ngineering Materials and Design

THE UNIVERSITY OF MICHIGAN
FEB 8 1960
ENGINEERING

FEBRUARY 1960
TWO SHILLINGS AND SIXPENCE

bricating Greases

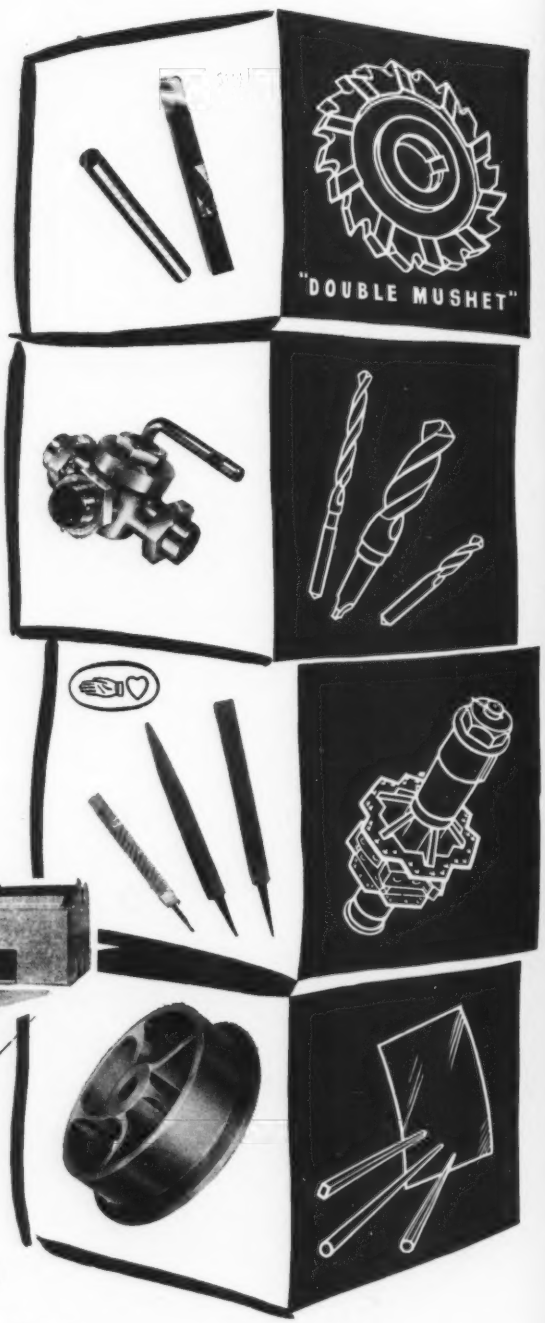
page 91

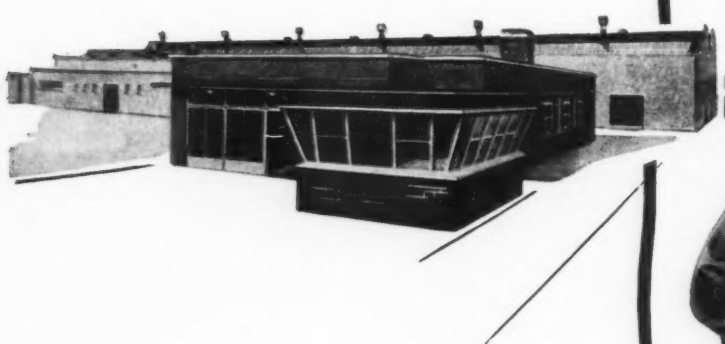
EMD 2064 for further information

BUILD YOUR EFFICIENCY WITH

OSBORN PRODUCTS

Integrated experience from over a century of craftsmanship has made the name of *Osborn* world famous as a hallmark of quality in the manufacture of fine steels and steel products. Products in alloy, stainless and tool steels are manufactured throughout within the same organisation, and include castings by general foundry and precision methods, forgings and engineers' cutting tools.





STEELMAKERS · STEELFOUNDERS · ENGINEERS' TOOLMAKERS

SAMUEL OSBORN & CO., LIMITED

CLYDE STEEL WORKS, SHEFFIELD

Engineering Materials and Design

★ *The Magazine for Engineering Designers*

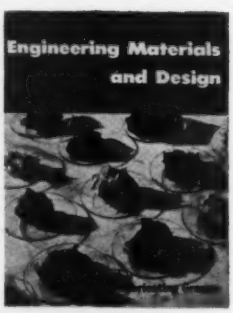
A HEYWOOD PUBLICATION

Vol. 3 No. 2 February 1960

EDITOR
H. R. Heap, B.Sc., A.M.I.E.E.

TECHNICAL EDITOR
R. D. Cullum, M.I.E.D., A.R.Ae.S., M.I.A.S.

ASSISTANT EDITORS
F. R. Terrell
P. Burton



COVER shows the many types and consistencies of grease available for a variety of applications. (Courtesy Shell Group of Cos.)

Published monthly by HEYWOOD & COMPANY LTD., Drury House, Russell Street, London, W.C.2 (Tel.: TEMple Bar 3422), on the 15th of the preceding month. Annual subscription 35s. sterling per annum ($5.25, U.S.A. and Canada) throughout the world. Single copies to order from all newsagents and bookstalls, 2s. 6d. each (by post from the publishers, 3s. 0d. each). BRANCH OFFICES: Royal Buildings, 2 Mosley Street, Manchester, 2, Tel.: Central 9935; Bayliss House, Hurst Street, Birmingham, Tel.: Midland 5786; 52 St. Enoch Square, Glasgow, Tel.: City 3492; 527 Madison Avenue, New York, 22, N.Y., Tel.: Plaza 9-1171.

© Heywood & Company Ltd., 1960
Must not be reproduced without written permission.

ISSUE AT A GLANCE

page

CHOOSING ELECTRIC MOTORS FOR UNUSUAL CONDITIONS 70
Correct types for specific environments.
By **C. Newton.**

HOW INDUSTRY CAN USE BERYLLIUM 79
Second of two articles on its fabrication and handling.
By **N. A. Hill**, B.Sc.

THE BONDING OF THREADED JOINTS 84
Official tests of commercial cements for thread bonding.
By **R. W. Bryant** and **W. A. Dukes.**

HOW TO SELECT LUBRICATING GREASES 91
Survey of the types available and their uses.
By **Molly Neal**, B.Sc., D.I.C., A.F.R.Ae.S.

DESIGNING COMPONENTS IN GLASS FIBRE-REINFORCED PLASTICS ... 96
A review of their possibilities and practice.
By **D. Pickthall**, B.Sc. (Tech.)

OTHER FEATURES

New Ideas in Design 77
Highlights at the Design Conference (preview of talks) 83
Designer's Notebook 87
Problems in Design—Readers' Solutions 88
Thermal Linear Expansion of Steel and Aluminium: Data Sheet ... 109
Beryllium Copper: Data Sheet 107

REGULAR FEATURES

Materials in the News ... 59
Editorial 69
Overseas Newsletter 103
New Books 110
New Materials and Components 113
News of Industry 121

CLASSIFIED ADVERTISEMENTS ... ... facing page 66

Résumés

LES MATIÈRES PLASTIQUES RENFORCÉES PAR DES FIBRES DE VERRE

par D. Pickthall page 96

L'auteur discute les matières premières employées dans ce procédé et les formes dans lesquelles les fibres sont facilement disponsibles. Les résines généralement employées sont comparées et leurs propriétés et avantages sont presentés dans un tableau. Les techniques de moulage sont expliquées d'une manière générale. Les propriétés spéciales des matières plastiques renforcées par des fibres de verre sont examinées et comparées aux celles d'autres matiériaux de construction dans les cas ou une telle comparaison est appropriée.

DES EMPLOIS NOUVEAUX POUR LE BÉRYLLIUM DANS L'INDUSTRIE

par N. A. Hill page 79

L'article constitue la deuxième partie d'une suite à deux parties sur les applica_tions actuelles du béryllium dans la construction mécanique. Dans cette partie l'auteur discute les propriétés physiques du métal en relation aux exigences du constructeur et passe en revue les techniques spéciales de manutention employées dans sa fabrication.

COMMENT CHOISIR LES GRAISSES

par Molly Neal page 91

Une revue des types principaux de graisses disponibles aux constructeur. L.auteur décrit les temperatures d'exploitation et autres propriétés des graisses-savons metalliques ainsi que des graisses " non-savons " et des graisses synthétiques introduites récemment. Un guide bref aux graisses disponsibles dans le Royaume-Uni est inclu.

COMMENT CHOISUR LES MOTEURS ÉLECTRIQUES POUR DES CONDITIONS EXCEPTIONELLES

par C. E. Newton page 70

L'auteur décrit les types principaux des moteurs électriques ainsi que les facteurs déterminant leur selection pour des conditions d'exploitation spécifiques, c.à.d. type d'encastrement, isolation, source d'énergie, grandeur, capacité calorifique, couple de torsion, commande vitesse, démarrage et freinage.

LA LIAISON DES JOINTS FILETÉS

par R. W. Bryant et W. A. Dukes page 84

L'emploi des ciments de marque pour la liaison des joints filetés (comme alternative à de telles methodes comme les contre-écrous) est actuellement à l'etude aux laboratoires de recherches sur les matériaux du Ministère de l'Aviation à Waltham Abbey dans l'Essex. Les resultats des expériences sur des boulons et des écrous d'acier (grandeur ¼") sont décrits et les conditions trouvées nécessaires pour l'application effective de ces ciments sont indiquées.

Kurzreferate

GLASFASERVERSTÄRKTE KUNSTSTOFFE

von D. Pickthall seite 96

Die in diesem Verfahren verwendeten Rohmateriale werden besprochen, sowie die Formen, in welchen die Fasern leicht erhältlich sind. Die allgemein benutzten Harze werden miteinander verglichen und ihre Eigenschaften und Vorteile werden in einer Tabelle zusammengefasst. Die Formverfahren werden kurz erklärt. Die Sondereigenschaften der glasfaserverstärkten Kunststoffe werden untersucht und wo anwendbar mit denen von anderen Konstruktionsmitteln verglichen.

NEUE ANWENDUNGEN VON BERYLLIUM IN DER INDUSTRIE

von N. A. Hill seite 79

Dieser Artikel ist der 2. Teil einer zweiteiligen Reihenfolge über die heutigen Anwendungen von Beryllium im allgemeinen Maschinenbau. Im vorliegenden Teil bespricht Verfasser die physikalischen Eigenschaften des Metalls im Zusammenhang mit den Forderungen des Konstrukteurs und beschreibt die besonderen, in seiner Herstellung angewendeten Handhabungsverfahren.

RICHTIGE AUSWAHL VON SCHMIEREN

von Molly Neal seite 91

Eine Übersicht der dem Konstrukteur verfügbaren Haupttypen von Schmieren wird gegeben. Verfasser beschreibt die Betriebstemperaturen und andere Eigenschaften der netallischen Seifenschmieren sowie jene von „Nichtseifen-" und neuerdings eingeführten Schmieren. Der Artikel enthalt eine Bezugsliste der in England erhältlichen Schmierentypen.

RICHTIGE AUSWAHL VON ELEKTROMOTOREN FÜR BESONDERE BEDINGUNGEN

von C. E. Newton seite 70

Die Haupttypen von industriellen Elektromotoren werden besprochen, sowie die ihre Auswahl für besondere Betriebsverhältnisse bedingenden Faktoren, d.h. Art von Gehäuse, Isolierung, Stromquelle, Grösse, Wärmekapazität, Drehmoment Geschwindigkeitsreglung, Anlauf und Bremsung.

VERKITTUNG VON GEWINDEFUGEN

von R. W. Bryant und W. A. Dukes seite 84

Die Anwendung von patentierten Zementen für die Verkittung von, Gewindefugen (als Alternative für solche Methoden wie Gegenmuttern) wird in den Werkstoffforschungslaboratorien des Luftministeriums in Waltham Abbey, Essex, untersucht. Im vorliegenden Artikel beschreibt Verfasser die Ergebnisse von Versuchen mit ½-Zoll Stahlbolzen und Muttern und gibt die zur erfolgreichen Anwendung der Zemente notwendig gefundenen Bedingungen an.

Резюме

ПЛАСТМАССЫ, УСИЛЕННЫЕ СТЕКЛЯННЫМ ВОЛОКНОМ

Д. Пикталл стр. 96

В статье обсуждается сырье, употребляемое в указанном процессе, а также легкедоступные виды волокон. Сопоставляются обычно употребляемые смолы, свойства и преимущества которых приведены в таблице. Формовочные процессы объясняются в общих чертах. Особенные свойства пластмасс, усиленных стеклянным волокном, сравняются с свойствами других конструкционных материалов, поскольку такое сравнение является применимым.

НОВЫЕ ПРОМЫШЛЕННЫЕ ПРИМЕНЕНИЯ БЕРИЛЛИЯ

Н. А. Хилл стр. 79

Вторая часть статьи в двух частях о современных применениях бериллия в общем машиностроении. В надлежащей статье обсуждаются физические свойства металла в зависимости от требований конструкторов, а также дается краткий обзор специальных технических способов обращения с ним.

О ПРАВИЛЬНОМ ВЫБОРЕ ГУСТЫХ СМАЗОК

Молли Нил стр. 91

Статья является обзором главных типов густых смазок, имеющихся в распоряжении конструкторов. Описываются рабочие температуры и другие свойства металлических мыльных смазок, а также «немыльных» и нововведенных искуственных смазок. Статья включает короткий список имеющихся в Англии типов смазок.

О ПРАВИЛЬНОМ ВЫБОРЕ ЭЛЕКТРОМОТОРОВ ДЛЯ НЕОБЫЧНЫХ УСЛОВИЙ

Ч. Э. Ньютон стр. 70

В статье описываются основные типы промышленных элетромоторов, а также факторы, определяющие их выбор для специфических условий работы, т.е. тип кожуха, изоляция, питание, размеры, теплоемкость, вращающий момент, регуляция скорости, пуск и торможение.

СВЯЗЫВАНИЕ РЕЗЬБОВЫХ СОЕДЕНЕНИЙ

Р. У. Брайант и У. А. Дьюкс стр. 84

В исследовательских лабораториях по испытанию материалов Министерства Авиации в Уолтэм Эбби, Эссекс, проводятся исследования в связи с применением патентованных цементов для связывания резьбовых соеденений (в качестве альтернативы для таких методов, как контргайки). В статье описаны результаты опытов на стальных полудюймовых болтах и гайках и указаны условия, которые оказались необходимыми для успешного применения данных цементов.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

British Racing Cars

MOTOR RACING has always been a challenge to engineers to design and build something which performs better than anything previously known. Very often racing machines are built at enormous cost and, as in the case of the Mercedes Benz organisation, the whole weight of the company's research, design and testing facilities are brought into use on a single project.

British supremacy in motor racing at the present time is not merely the result of other countries losing interest but is the culmination of British engineering skill and ingenuity over many years. Enzo Ferrari himself recently admitted that the success of British machines was not the least surprising because for many years his cars were entirely dependent on British-made brakes, bearings, tyres, and materials such as zirconium and titanium. The recent Racing Car Show, organised by the British Racing and Sports Car Club Ltd. was a praiseworthy effort to publicise the many successful racing machines recently developed in this country, but it is a pity that the automobile industry does not itself take on the responsibility for displaying not only the finished cars but also the many accessories which have been developed initially for racing and ultimately for normal production cars. There is no finer example of British engineering than in the racing car.

Protecting Molybdenum from Oxidation

FOR MOLYBDENUM to compete successfully with nickel-based alloys in high temperature applications (such as are encountered in gas turbines) it is essential that it be protected from oxidation. Various materials, foremost among which are chromium, nickel, silicon, precious metals and ceramic materials and refractory oxides, are at present being investigated as coating materials.

Methods of application of coatings often determine the quality and protective capabilities of the coating, and the usual methods include electroplating, flame spraying, vapour deposition, cladding, enamelling and liquid phase diffusion. The behaviour of inherently porous electro-deposited coatings may be improved by the application of duplex layers. Among the most promising electro-deposited coatings is chromium plated with nickel. A technique recently demonstrated at the Armament Research & Development Establishment at Fort Halstead, uses multi-layer coatings of alternately 0.0002 in. of chromium and 0.0008 in. of nickel, the resulting products being then tested at 1100 deg. C. in an atmosphere of convected air. The presence of molybdic oxide in the air passing upwards through the furnace and thence through a glass tube was immediately detected by a light cell which, by operating a relay, shut off the current to the furnace. Time to failure is automatically measured. This "onion-skin" technique is believed to create a coating similar to Nimonic alloy by diffusion, and coatings of ten mil thickness have in some cases given a life of 550 hours.

Molybdenum disilicide coatings are characterised by excellent time-temperature capabilities and good thermal expansivity match with molybdenum, but are also inherently brittle.

Precious metal coatings are inherently resistant to oxidation, ductile and compatible with molybdenum and their thermal expansions coefficients compare quite favourably with that of molybdenum.

Ceramic or glass base coatings may be matched to molybdenum to provide excellent thermal expansion characteristics. The addition of crystalline solids such as chromium, and zirconia have been found to improve the adherence and protective qualities of glass coatings. Refractory oxide coatings may be matched to molybdenum for good thermal expansion characteristics and these coatings have high hot hardness and are brittle, but have relatively low thermal conductivity.

Clad coatings are uniform and continuous, but special precautions are necessary to preserve continuity at sheared edges and joints. Limitations common to vitreous enamelling regarding uniformity of coating at corners or in recesses apply equally to coatings on molybdenum. Liquid phase diffusion processes have been under investigation, but are not so practical as other methods in most instances.

New Rubbers

ALTHOUGH IT SEEMS LIKELY that natural rubber will be in great demand for some years, there is a clear possibility that in time it will be displaced by synthetic or modified natural rubbers. Recent discoveries that led to the development of synthetic "natural" rubber may overshadow the importance of more exotic pure synthetics, because for commercial reasons it is very desirable to have available a rubber which is not dependent on imports from the Far East and it is likely that a more consistent product will be obtained.

However, the purely synthetic rubbers will still be of great importance technically, and a material of interest is ethylene-propylene copolymer, developed in Italy, but now available in small quantities. Another special group, known as "Adduct" rubbers, is proposed for the construction of a giant airship which may well be the world's first nuclear powered aircraft. It has been recommended for coating Dacron to cover the 4½-million cu. ft. body of the airship, on account of its resistance to radiation and its excellent ageing and diffusion characteristics. In June last year a new rubber-based material was announced for use in atomic powered planes for shielding the crew and passengers from radiation. In this application it replaces concrete and water shields and exceptional stability under intense radiation is claimed for this material. Rubbers are now also being used, according to Goodyear, to mix with high energy fuels for rockets. The rubber and fuel is mixed while in liquid state and solidify on cooling in the missile. Simple rocket engines are made possible by this means.

Battelle scientists have recently pointed out that Russia announced the development of synthetic natural rubber, known as SKI, within two years of the U.S. breakthrough. The Russians expect to use this material for about one-quarter of their tyre production by 1965 and this may well foreshadow a similar progress in the U.S.A. and this country.

Insect-proof Screens

ONE OF THE PROBLEMS associated with the design of electrical engineering products for use in tropical countries is the exclusion of insects, but some recent results by medical workers in Russia suggest an interesting solution. They have found that the use of a vinyl plastics and glass fibre screen treated with resin to strengthen the fibres gives good protection to buildings from insects such as mosquitoes and other blood-sucking insects. One important point claimed for these screens is that they allow the free passage of air and this is an important factor in cooling of electrical equipment. Dust can be easily removed with a brush, a damp cloth or by washing with water and they are flexible so that they can be rolled up for storage.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN

RECORD ALUMINIUM SPINNINGS

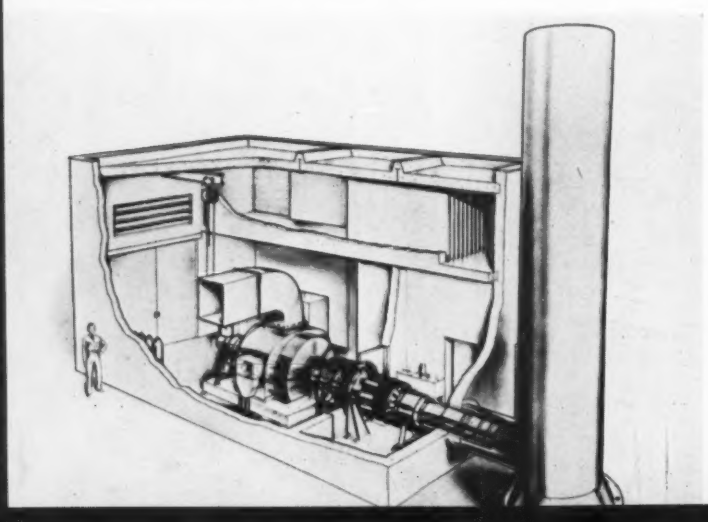
What are believed to be the largest spun aluminium ends produced in this country have recently been completed by G. A. Harvey & Co. (London) Ltd. They have an inside diameter of 10 ft. and are 1⅛ in. thick. Each end was spun from two plates, butt welded to form a flat disc 12 ft. in diameter. They are to be used for pressure vessels which will contain liquid air.

TEMPERATURE TEST CHAMBER

This extreme temperature test chamber is designed principally for use with Instron tensile testing instruments and makes possible tensile and compressional tests at a temperature range of from − 95 to + 1000 deg.F. Used individually, it can be an oven or cold chamber, with working space of about 3,000 cu. in.

AUTOMATED POWER STATION

A Bristol Siddeley 3 MW turbo generator of the type illustrated below has recently been installed at Princetown, Devon. By using the telephone dial on a control panel (photo, below right), the unmanned power station is automatically started from a control centre 100 miles away, and steps up within minutes up to full output at 11,000 volts. Control unit is a Datofonic system developed by Sound Diffusion Ltd.

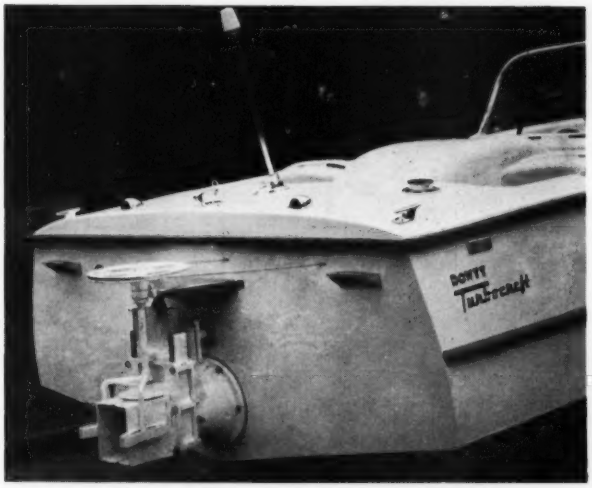


GLASS FIBRE RADOME ▶

The Consort small craft equipment is a departure from the usual type of marine radar. It works from a 24-volt battery and keeps power consumption to a minimum. The aerial unit shown here is protected by a radome made of two skins of glass fibre-reinforced plastics separated by a core of low-loss foamed plastics. It is made by Marconi.

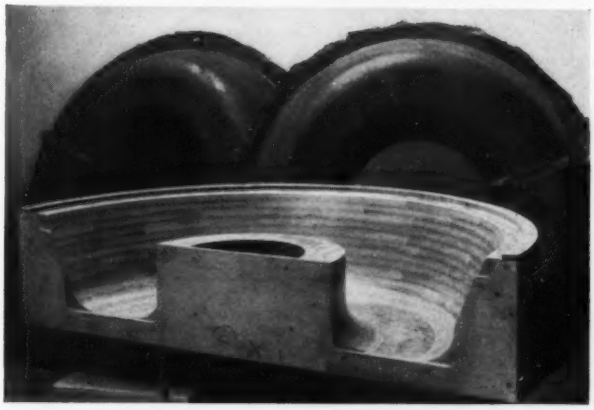
FOR TURBO BOAT ERA ▶

This new craft lately demonstrated by Dowty Marine Ltd. has as a power unit a standard marine Ford Zephyr Mk. II engine driving a two-stage Hamilton-Dowty jet unit. Water is drawn through a grid in the bottom of the hull and ejected through the stern to give both steerage and reverse. It has a draught of 9 in. It is 14 ft. 6 in. in length and is made entirely of polyester glass fibre.



MOULDS FOR GLASS FIBRE

A densified wood laminate made from beech veneers interleaved with glue film is said to be proving a successful mould material for glass fibre production. Called Hydulignum, in various densities from 60 lb./cu. ft. upwards, its main use is said to be in cases where wet lay-up and low pressure curved moulds are required. Picture shows a mould used to produce glass fibre baffles.

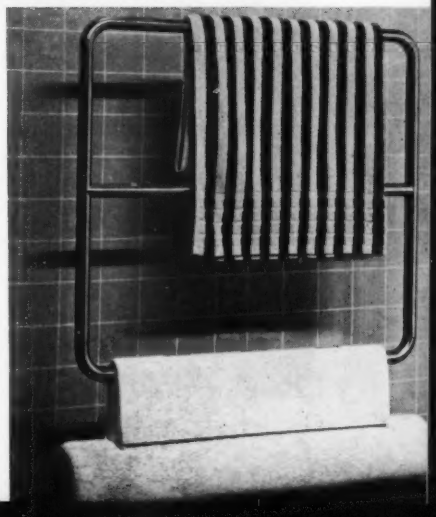


THREE-PURPOSE RADIO ▼

This three-purpose transistorised radio by Murphy is said to be unique. It can be carried in a special case for picnics; it can be put in a timber cabinet for home use; and it can be used as a car radio by connecting to the car battery. Radio case is in polystyrene moulded by Insulators Ltd.

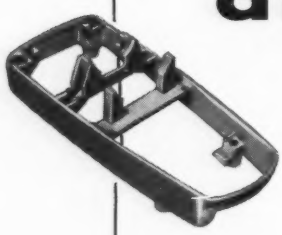
PARAFFIN FUELLED ▶

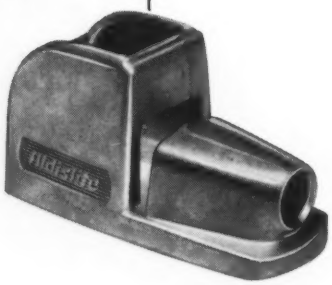
This Paramatic towel rail consists of a sealed tubular system filled with a fluid which is heated and circulated by an automatically controlled paraffin oil burner. It is equipped with a thermostat and needs filling only every three weeks.



WOLVERHAMPTON

die casting





. . . help Aldis to produce precision equipment at minimum cost

Precision, strength and high-quality finish—these are the prime requirements of Aldis Brothers Ltd. for their Aldislite Slide Projector.
WOLVERHAMPTON die castings meet these requirements, in the largest and most modern plant in the country, backed by nearly half a century's experience in the making of quality die castings.

THE WOLVERHAMPTON DIE CASTING CO. LTD.

GRAISELEY HILL WORKS, GRAISELEY HILL, WOLVERHAMPTON Telephone: 23831/6

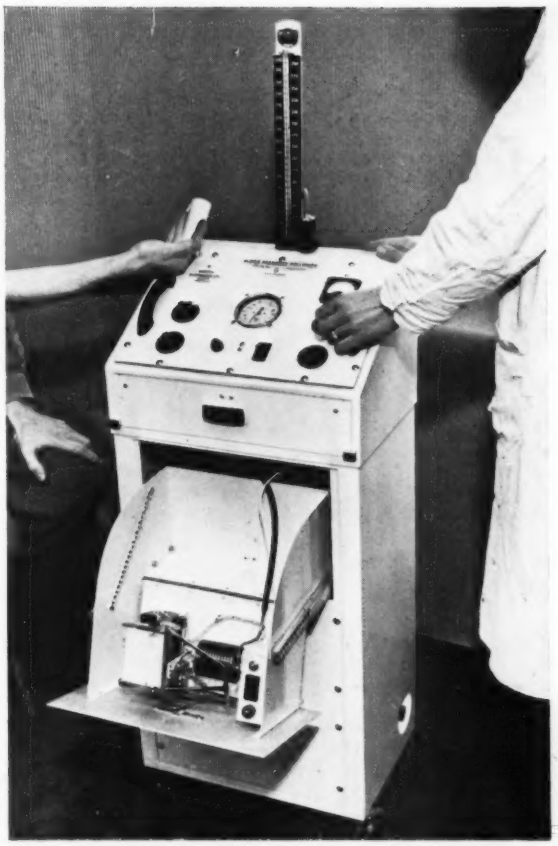
Half a million square feet devoted to the production of better die castings

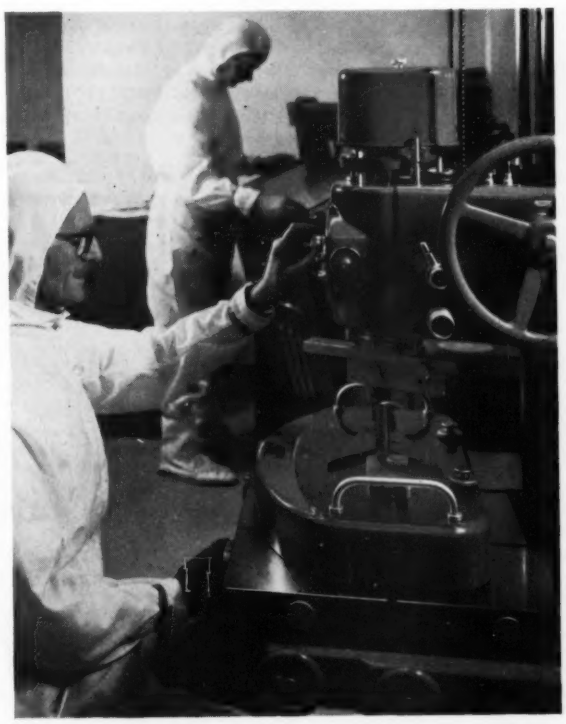
Engineering and Medicine

MODERN MEDICAL TREATMENT owes much to the development of new materials which will not corrode in contact with body fluids and will not contaminate them Dr. W. J. Kolff, of the Dept. of Artificial Organs at Cleveland Clinic and who developed the artificial kidney, has now turned his attention to artificial hearts and valves and in this work good use has been made of a new polyurethane plastics developed by the B. F. Goodrich Co. This material, known as Estane VC, is rubbery and is said to show excellent resistance to weathering and abrasion without the need for a vulcanising process. Other possible uses include cable sheaths and inflatable products. Engineering is playing an ever-increasing part in the construction of medical equipment such as the Barnet ventilator which was developed by W. Watson & Sons Ltd. for the control of a patient's breathing. This equipment, which is much more portable than the "iron lung" and leaves the patient much freer to move about, consists essentially of a double-acting pump controlled by solenoid-operated valves. Variable timers can be set to regulate breathing at a pre-determined rate or alternatively the patients natural breathing can be used to initiate the operation.

The flow of knowledge is by no means one way, for medical experience is being put to good use in designing artificial limbs and remote control mechanisms for handling radioactive materials. A glimpse at one of the many factories engaged in the manufacture of semiconductor devices, high precision gyroscopes or radio valves discloses a state of cleanliness which is as good if not better than that of a hospital operating theatre.

Electronics have made a particularly marked impact on medicine, and so rapid has been the progress that conferences are being held annually on an international basis for the exchange of ideas and techniques; the next is being held by the Institution of Electrical Engineers in London in July and doctors, biologists and engineers are being invited from all over the world.





The mutual influence of precision engineering and medicine: (above) the Winston-Green blood pressure follower, and (below) monk-like technicians at work in the new dust-free Ferranti laboratory.

Another Plastics Exhibition

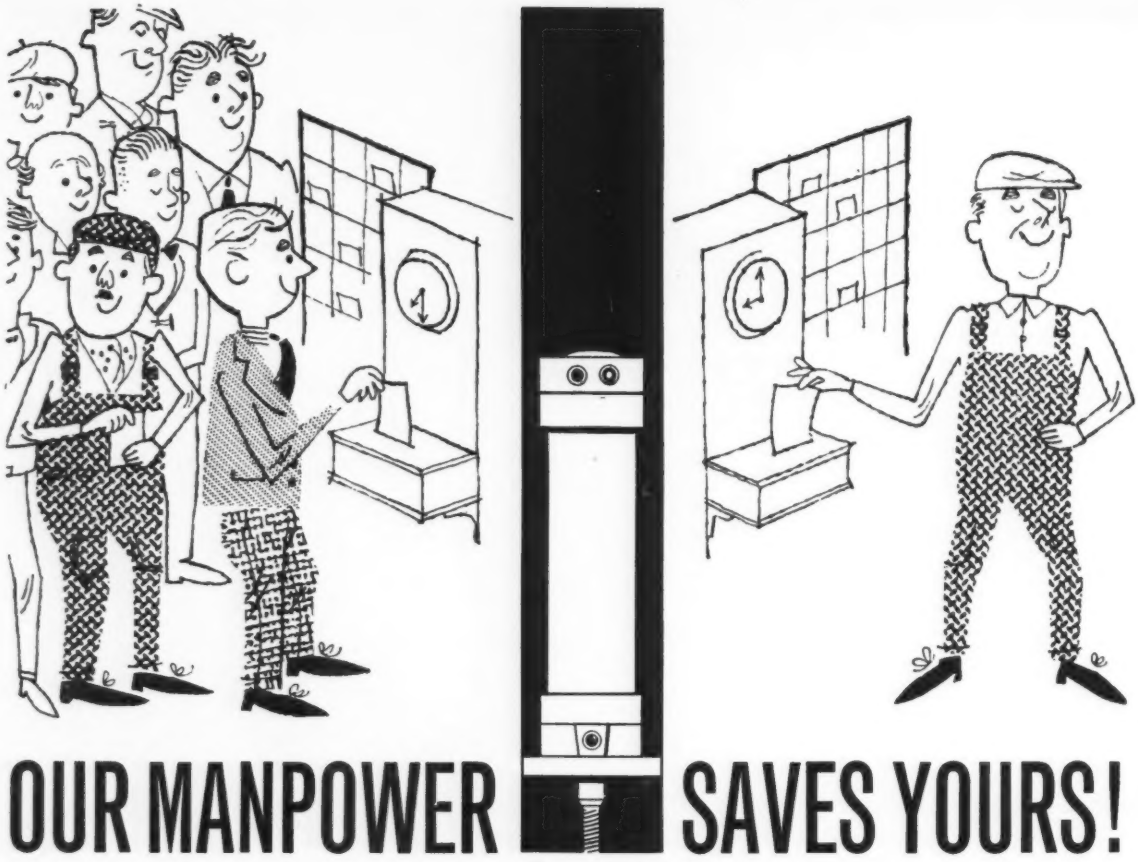
PLASTICS EXHIBITIONS get bigger and more numerous every year and now, not long after the mammoth Dusseldorf Kunststoffe exhibition, comes news of the second "Macroplastic" exhibition to be held in Utrecht from October 19-26 this year. The exhibition will be truly international and one hall will be devoted to information and advice about the application of plastics. In this hall exhibits will be grouped into industries so that visitors can quickly see the progress of plastics in his own particular field; this is an interesting innovation which might well be followed by other large exhibitions.

International Safety Centre

EARLY THIS YEAR the industrial safety division of the Royal Society for the Prevention of Accidents is to begin its part in an international scheme intended to promote wider understanding of industrial safety and allied subjects among safety officers, works managers, industrial physicians, trade unionists and research workers. The essential aim of this scheme is to make information available, rapidly and systematically, on literature and legislation dealing with all aspects of occupational safety and health. Every type of industrial activity will be covered, including engineering, mining and quarrying, agriculture, transport, dock work, public services and civil engineering.

Distribution of the information will be made through the International Labour Office by means of index cards. Literature to be dealt with will include reports and specialised publications of all descriptions, and books and periodicals from countries throughout the world. Laws and regulations, codes, standards, specifications, instructions and other texts of a legislative nature will also be given systematic coverage.

Other countries co-operating with the I.L.O. in this scheme are France, Germany, Italy, Austria, Belgium, Denmark, the Netherlands, Poland, Sweden and Switzerland. Each of the national centres in these countries will be responsible for supplying to the I.L.O. abstracts of information affecting industrial safety and health published in their countries. The I.L.O. will undertake the work of transferring this information to the index cards already referred to and re-distributing them.



OUR MANPOWER SAVES YOURS!

In almost every industrial process there is some stage where manpower could be cut by the application of fluid power. It is here that our labour can prove so labour-saving, since the whole weight of the Baldwin Fluid Power Division is directed at cutting waste manpower and speeding production.

BALDWIN TECHNICAL REPRESENTATIVES cover the British Isles. They are experienced fluid power engineers, who will quickly show you how to harness waste or under-used power by fitting Baldwin equipment which, because of its unit construction, can be supplied from stock quickly.

Write now for the Fluid Power Catalogue EM/503

THE EXPERT BALDWIN DESIGN STAFF at Dartford will plan automation schemes for any operation or series of operations up to the largest automatic production lines.

HIGHLY SKILLED MEN on the Baldwin shop floor devote their attention to producing the superb finish, reliability and precision that characterises Baldwin Fluid Power equipment. There is a standard range of 384 pneumatic and hydraulic cylinders and over 700 control valves.

We have long found that the best way to success is to give the best service. At every level, our manpower is aimed at increasing production for industry —and for Baldwin too, of course!

Fluid Power Division

Baldwin Industrial Controls

Baldwin Instrument Company Limited · Dartford · Kent

Telephone Dartford 20948 & 26411 · Cables & Telex Baldwin Dartford

A HARPER GROUP COMPANY

B/55

High Temperature Strain Gauges

A CONSIDERABLE AMOUNT of work on high temperature strain gauges has been in progress over the past few years. Rolls-Royce Ltd. have been developing a wire strain gauge especially for measuring alternating stresses with particular reference to compressor and turbine blades. Along with the development of the strain gauge has been a parallel development of adhesives suitable for temperatures up to 800 deg. C. Fairey Aviation Co. Ltd. have developed for their own use a self-compensating strain gauge for temperatures up to 250 deg. C. where the temperature is slowly varying. Development work is also proceeding on high temperature cements.

The A. V. Roe strain gauges are either resin-based for temperatures up to 250 deg. C. or ceramic-impregnated glass-based for temperatures up to 750 deg. C., the latter being particularly suited for heat resistant steels. Temperature compensation using thermocouple compensated gauges shows promising results.

Foil strain gauges for use up to 300 deg. C. with either an epoxy ethylene backing or a plastics strip-off backing have been marketed by Saunders-Roe Ltd., these being the low resistance 40-80 ohm type. High resistance foils are being developed and also gauges which are suitable for use up to 800 deg. C.

Dynamic strains at temperatures up to 600 deg. C. have been successfully measured by de Havilland Propellers Ltd., using an American high temperature foil gauge, and a compound wire type temperature compensated gauge has been developed for temperatures ranging from – 196 to +200 deg. C., these being paper-based and phenolic impregnated.

Bristol Aircraft Ltd. have been working for some time on the development of strain gauges and techniques for use up to 300 deg. C. At present, wire wound resin impregnated gauges with phenolic resin cement are being used, and investigations at present in hand are directed towards temperature corrections applicable during radiant heating.

Transplant Coatings of Aluminium

TO OBTAIN wear-resistant properties, four production techniques may be applied to aluminium cylinder barrels. They are: wet steel sleeves, transplant coating for sleeves as well as engine block bores, cast-in sleeves, and high-wear aluminium alloys.

Dry sleeves are usually cast or pressed into the bore of an engine. The casting process is good if a bond can be formed between the sleeve and the block but normal casting procedures may produce shrinkage away from the sleeve in the heavier sections, resulting in voids and hot spots in the sleeves. One way to overcome this problem is by using a centrifugal casting for the sleeve and retaining its rough outer surface. Die cast aluminium is then forced into the spine-like openings in the cast iron, forming an interlocking surface.

Wet sleeves can be made of iron, aluminium with a high-wear surface, or a high wear (hypereutectic) aluminium.

Cast-iron sleeves are usually used in conjunction with a steel deck plate. This results in some expansion problems and gives rise to galvanic corrosion. However, the oil retention for cold starts is good with cast iron and its wear properties are well known.

With aluminium wet sleeves there is no expansion or corrosion problem and the advantages of lighter weight and better thermal conductivity are realised, but the bore of the sleeve must be protected against excessive wear. Two methods are already in use—porous chromium plate and sprayed molybdenum-iron coats, the major disadvantage of these methods being cost. A third, relatively new method is the use of a transplant coating.

Transplant coatings are made by depositing metal on the core of the die that produces the cylinder bore. The injected aluminium then shrinks onto the rough outside of the sprayed coat. Because of differential expansion, the coating stays with the aluminium die casting and creates a taper-free bore of extremely high smoothness (30 r.m.s.) and a high accuracy (± 0.003). Only a slight honing operation is needed to finish the bore. The coating can be made of almost any material in any thickness and porosity.

Electronic Reliability Centre

THE OPERATION of an electronic component reliability centre has been recently established at the Battelle Memorial Institute. This centre for research and information is supported by eleven U.S. users and manufacturers of electronic components who are pooling reliability data.

Many firms are accumulating large amounts of data of this kind from work on missiles, space vehicles, supersonic aircraft and electronic computers, and Battelle recognised a need to co-ordinate this and avoid duplication, in the belief that such group effort would have a higher degree of validity than individual work.

Firms participating in the centre include Bell Telephone, Boeing Airplane Co., I.B.M. Corp., Lockheed Aircraft Corp., Martin Co., Motorola Inc., Raytheon Co. and R.C.A.

Porosity of Plated Coatings

BECAUSE THE PROTECTIVE VALUE of a plated coating on metal is dependent to a large extent on the exclusion of pores and other flaws in the coating, the National Bureau of Standards has been investigating the causes, nature and effect of porosity in plated coatings. Various aspects being studied include the development of an improved technique to study the porosity of metallic electroplated coatings with a microscope. Further knowledge of electroplating and a satisfactory method of measuring the porosity should be of value both to the plating industry and to the science of electroplating.

Although much research has been directed toward pore detection and elimination, methods of examining pores on metallic coatings with microscopes have received little attention because most pores have diameters too small for adequate sectioning. Even if a pore is sectioned properly, the contours may be distorted by polishing and etching. So far, attempts to cut an entire pore parallel to its axis have been unsuccessful, so that a dot or oval is all that is seen.

"Parallel sectioning" is a technique involving polishing off some of the coating perpendicular to the axis of the pore and parallel to the base metal. When the cut section is studied under a microscope, the pore will appear as a small dot which can easily be seen at 400 magnification if the pore is larger than 0.05 mil. in diameter. To make sure that the dot is not a surface defect introduced during polishing, successive layers are removed and examined until the underlying metal is reached. If the dot is a pore, it will reappear consistently at the same spot. A pantograph arrangement is used to relocate the exact position of the pore after successive removal of each layer.

With this technique, the size and shape of pores or other defects that are difficult to cross section can be determined and the damaging effects of atmospheric corrosion can be further studied.

EXTRA FEATURES NEXT MONTH

in Engineering Materials and Design. The March issue) to appear in mid-February) will carry additional technical articles, as well as a special preview of the first Engineering Materials and Design Exhibition being held at Earls Court from February 22-26. Main articles will include:

Silicones in Engineering
A material that has many engineering roles.

Miniaturisation
Its impact on current engineering practice.

Sources of Technical Information
Where to go for up-to-date research and development data.

Refractory Fibres in Industry
Fused silica for use at elevated temperatures.

Molybdenum and Tungsten Alloys
Their special value for tools and cutting edges.

Designing for Forgings
Basic principles and its potential.

How Designers Can Use Extrusions
Aluminium extrusions for structural and decorative use.

This is the new Citroen Bijou which is currently being built in the U.K. of fibre glass-reinforced plastics

Glass Fibre Car

THE BIJOU, the new small car which was specially designed by Citroen for the British market has a number of features which, if not unique in themselves, together comprise an outstanding little car. The body, being built by Jas. Whitson & Co. from glass fibre and Cellobond polyester resins, is made in five units, i.e. the body, the two doors, the front-lift bonnet and the boot lid, to a design to suit the 2CV chassis. There is a unique independent suspension system which makes for excellent comfort. Inertia clamps on all wheels completely absorb shock and vibration and relieve driver fatigue.

Adhesion with Polythene

RESEARCH IN THE FIELD of adhesives at the Massachusetts Institute of Technology has resulted in making previously non-stick substances highly adhesive. A theory of Mr. J. J. Bikerman, supervisor of the adhesives laboratory, was that one material fails to adhere well to another because chemical impurities and low-weight molecules cause a tiny boundary layer to form between the two. This surface film is weak, so that any stress causes a break or tear along the film. The effect may be caused by a phenomenon known as "syneresis."

Using polythene, he has shown that breaks and ruptures do occur in this boundary layer area. In tests, he chemically removed the impurities and made polythene cling tenaciously to various metals, glass and plastics.

The process of removing the low-weight molecules and impurities is called fractional crystallisation. The material is dissolved in boiling solvents such as cyclohexane or toluene. When precipitated with acetone, polythene can be used as an adhesive between steel and steel, steel and glass, glass and glass, glass and aluminium, and so on. Peeling tension of aluminium-polythene-glass joints registered up to 90 oz./in.

The results are said to show a significant improvement in the adhesive qualities of many types of materials.

New Thought for Welding Design

IN THE PRESENT AGE metal fabrication without welding would be unthinkable. In almost every field welding in one form or another plays a major part, and the results are seen in the development of mass-production methods, in metal economy and in the aesthetic lines of the welded structure. As however welded fabrication is a comparatively new process a new attitude to design, as applied to the welded structure, is essential to exploit all its advantages.

The problem is one of national importance, and the Department of Scientific and Industrial Research is supporting a special scheme to assist in speeding up the application of design and welding research results in industry. This support is enabling the British Welding Research Association to form a new design advisory service to show its members how research work can be applied at all stages of design, from the choice of right materials and selection of the most suitable welding process to the correct method of assembly.

Scotland's Design Problems

SHORTLY BEFORE he retired a few weeks ago as director of the Council of Industrial Design, Sir Gordon Russell had some comments to make in the council's annual report on the special problems facing designers in Scotland. "Design problems in Scotland," he said, "are more intractable than those in the south, in view of the high proportion of heavy industry and the comparative isolation of many towns."

Our own correspondent, who recently toured a number of Scottish industrial concerns, came to the conclusion that too many firms established from the last century are showing little inclination to step outside their traditional mode of design, with equally little tendency to train future designers. Smaller newcomers find it difficult to achieve substantial orders from Scottish firms and are forced to seek work from south of the border. An influx of larger companies concerned with mass production of goods is needed.

Two reasons may be offered for this tardiness; one is that much of Scottish money is invested in trusts and undertakings outside Scotland rather than in home engineering projects. The other possibility is technical ability. The Scot has traditionally been associated with engineering, but in a physical sense rather than a design one. It may be significant, perhaps, that many companies which are expanding and adapting to current conditions are those whose technical direction is in the hands of non-Scots. There are fortunately some notable exceptions.

Foaming Plastics on Site

THE USE OF FOAMED PLASTICS has already valuable application in building construction for insulation work. Materials of this type (i.e. based on p.v.c. or polystyrene) have for some time been available in sheet or block form which were then cut to shape. For certain conditions, where there are numerous cavities and irregularities to be dealt with, this method had some limitations. A British firm has now developed equipment and a material which can be foamed and simultaneously filled into inaccessible places, which might otherwise be uneconomic to insulate.

Marketed under the name of Jablinsul, and made by Jablo Plastics Industries Ltd., the insulation material is directed through a nozzle under air pressure into awkward corners. It hardens in this form after 20-30 min., but because of its light weight and viscosity it remains in place and does not move even in vertical and inverted applications; no shuttering is needed to support it.

New Nickel Alloys

HITHERTO, the Nimonic series of high-temperature alloys have all been produced by air-melting techniques. It is, however, generally accepted that melting in vacuum results in the development of even better high-temperature properties, especially if the composition of the alloys is adjusted to take advantage of the higher purity that can be maintained by this technique.

Although not yet commercially available, five new alloys of improved properties are in the process of development in the research laboratories of the Mond Nickel Co. Ltd., and may eventually be added to the Nimonic range. Three are wrought alloys and two are casting materials.

FOR MORE INFORMATION:—

Jablo Industries Ltd., Waddon, Croydon.
Battelle Memorial Institute, 24 Ryder Street, London, S.W.1.
Goodrich-Gulf Chemicals Inc., 3121 Euclid Avenue, Cleveland 15, Ohio.
Massachusetts Institute of Technology, Cambridge 39, Mass.
British Welding Research Association, Abington Hall, Cambridge.
Royal Society for Prevention of Accidents, Artillery Mansions, 75 Victoria Street London, S.W.1.
Winston Electronics Ltd., Shepperton, Middx.
B. F. Goodrich Co., Akron, Ohio.
Macroplastic, Tesselschadestraat 5, Amsterdam.
Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent.
British Racing and Sports Car Club Ltd., 6 Buckingham Street, London, W.C.2.
Winston Electronics Ltd., Shepperton, Middx.
Jas. Whitson & Co. Ltd., High Street, Yiewsley, W. Drayton.
W. Watson & Sons Ltd., 313 High Holborn, London, W.C.1.

NOW THE N. R. D. C. FIRES BACK

IT is not unusual for industry to criticise Government departments for their lack of initiative and slowness to appreciate the significance of technical developments, but an exception must be made for the National Research Development Corporation which was set up to secure, among other things, the proper development of important or useful inventions which were not being exploited elsewhere. The tenth annual report on the Corporation has just been issued and this seems to be an appropriate moment to review its work and see how far it has been able to stimulate activities which industry has not by itself undertaken. A brief look at the financial position discloses what appears to be merely another Government undertaking losing money, because only about one-third of the Corporation's expenditure of about £930,000 was met by revenues, the remaining £620,000 being borrowed from the Board of Trade. It should be realised, however, that by far the greatest proportion of the revenue comes from the exploitation of inventions, and this is necessarily a long-term project. It is very encouraging to hear that, although the Corporation is only just over ten years old, some of the inventions it is exploiting are, perhaps surprisingly, already showing a profit, even though the patents involved still have some years to go. Financially, therefore, it is still early to draw conclusions as to whether the Corporation's work is justified, although one has a strong suspicion that in the end it may well have the final laugh at industry, which has turned down as unprofitable some of the inventions the N.R.D.C. is exploiting.

The work of the Corporation covers many technical fields besides those of engineering, but it is doubtful if anything yet sponsored by the N.R.D.C. has received so much publicity as the Hovercraft. The decision to sponsor Mr. C. S. Cockerell's invention was taken in September 1958 and within ten months the first public demonstration of the craft as well as a crossing of the English Channel were made. This must be something of a speed record for Government - sponsored development and compares very favourably with privately-sponsored developments of comparable size.

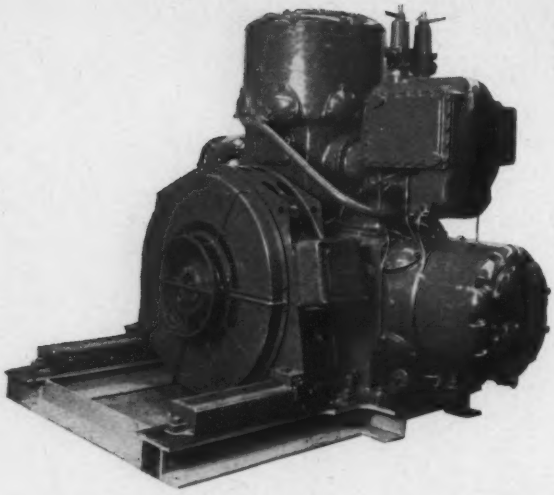
Another development also receiving tremendous publicity is the hydrogen-oxygen fuel cell, which has for many years been a rather unwanted child and only because of the persistence and faith of its inventor, Mr. F. T. Bacon, has it survived at all in this country.

We hear that as a result of the publicity considerable serious interest has been aroused and, while this is certainly good news, it really makes one wonder what industry is playing at. The Electrical Research Association issued many reports of the fuel cell researches, but apparently the misleading headlines of the daily Press were more effective in rousing the enthusiasm of possible users, in spite of the fact that the N.R.D.C. demonstration of operating a fork lift truck on the end of a long cable was hardly as convincing as that of the Americans, who recently showed a tractor powered by a built-in fuel cell.

Many other developments with interesting engineering possibilities are also being carried out, such as pitch stabilisers for ships, printed electrical circuits and the somewhat revolutionary variable-speed induction motor of Prof. Williams.

The N.R.D.C. seems to be doing a very good job and, if we must criticise, it is that the whole project is on too small a scale. What about supplementing it with a private enterprise research and development corporation? The capital required would be no greater than for many of the present nuclear energy consortia and the possibilities of making a profit are at least as good!

The Editor



Crompton Parkinson 400-h.p. synchronous motor driving a two-stage double-acting Broom & Wade compressor.

CHOOSING ELECTRIC MOTORS FOR UNUSUAL CONDITIONS

Every motor application has its special problems, but a combination of adverse conditions may call for special care in selection; here is a guide to evaluating these factors

by C. E. NEWTON*

IN choosing an electric motor for a specific application the problem is to find the most economical type and size to give reliable and trouble-free operation, with the minimum of maintenance. Before final decisions are made it is supremely important that the motor manufacturer be given all relevant facts, as, knowing the exact capabilities of a particular motor and in many cases having experience of supplying motors for the application in question, he can be of considerable assistance in choosing the best motor for the duty, and the factors below considered.

To obtain an idea of suitable types and the correct size of motor the speed torque characteristic required by the load should be compared with the motor characteristics given in Figs. 1-7.

Consideration will be somewhat arbitrarily limited to the following types, representing the majority of motors, other than fractional horsepower, used in practice:

A.C. squirrel cage and wound rotor (slipring) induction motors.

A.C. synchronous and synchronous induction motors.

A.C. commutator motors (Schrage, i.e., movable brush, type).

D.C. shunt, series and (cumulative) compound motors.

The relevant British Standard for electric motors of the size considered is B.S. 2613 : 1957. Appendix "B" in this lists the information which should be—and so rarely is—given to the motor manufacturer.

General Considerations

TYPE OF ENCLOSURE—This will be determined by the conditions in which the motor must operate. In a good atmosphere, for example, ordinary screen-protected motors can be used. Motors working in otherwise clean atmospheres, but subjected to a "rain" of particles or water, may have a drip-proof, splash-proof or hose-proof enclosure depending on the severity of the "rain". The restricted ventilation of splash-proof and hose-proof enclosures, however, usually means increased size, and cost. To exclude frogs, mice, large insects, etc., from the motor all openings may be covered with fine wire mesh.

Motors used in slightly polluted atmospheres may be screen protected with specially treated windings. Care must be taken in this as trouble may occur on commutators and sliprings. Some makes of slipring induction motors have external sliprings which can be made totally enclosed to preclude this trouble.

It may be possible to use a pipe ventilated motor if a clean air source is sufficiently near. If not, the same result may possibly be achieved by a filter to remove dust, sand, droplets, etc.

If the atmosphere is highly polluted (e.g., by carbon black in rubber factories, or by chemicals), an enclosure must be used relying on a closed-circuit circulation of cooling air. Normally the size limit for plain totally enclosed motors is about 50-70 h.p. per 1,000 r.p.m. For d.c. motors up to about 150 h.p. per 1,000 r.p.m., and induction motors to about 1,000 h.p. per 1,000 r.p.m., totally enclosed fan-cooled motors may be available. For other types and sizes closed air circuit motors with external water-cooled heat exchangers tend to be used.

The use of totally enclosed fan-cooled motors in places where clogging of the external cooling ducts is likely should be avoided, as this could lead to overheating and breakdown due to insulation failure.

TYPES OF INSULATION—Comparable temperature rises permissible in an ambient temperature of 40 deg. C. on similar windings insulated with different types of insulation are as follows:

Class A	Class E	Class B	Class F	Class H
55°C.	65°C.	75°C.	95°C.	115°C.

These rises are based on the need to keep the temperature of the insulation below that at which its insulating properties are affected, in order to give a reasonable motor life.

Most manufacturers have several ranges of motors based on class A insulating materials and temperature rise, and recently many have introduced ranges based on class E insulation.

If insulation is used which allows a higher temperature

* *Crompton Parkinson Ltd.*

rise than the standard for the range, the manufacturer will either have to modify his design considerably to meet the torque capacity requirements (see below), or ignore the permissible temperature rise and supply an otherwise standard motor having special insulating material, since a normal design of motor with the output increased to give the permissible temperature rise would not have sufficient torque capacity. As either of the above expedients would tend to make the motor costly, non-standard insulating material should generally be avoided, except in special cases as, for instance, when the motor is to operate in a higher than 40 deg. C. ambient with corresponding reduction in temperature rise to keep the total temperature to a value which is safe for the insulation. Then the cheapest motor would normally be that for which the insulation class was chosen to give the normal temperature rise for the range of motors (e.g., if the range of motors were based on class A materials, and a temperature rise of 55 deg. C. in an ambient of 40 deg. C., then a motor to operate in an ambient of 60 deg. C. would have the 55 deg. C. temperature rise typical of the range if class B insulating materials were used, since 55 deg. C. rise in 60 deg. C. ambient gives the same maximum temperature as 75 deg. C. rise in 40 deg. C. ambient).

For motors with special overloads the determining factor may not be the temperature rise, and specifying non-standard insulation may be a waste of money.

Reduced efficiency is normally concomitant with high temperature rise.

SUPPLY—The effect of the motor as a load on the supply should be considered. In particular, high starting currents may cause considerable reduction in voltage at the motor terminals, due to voltage drops in transformers, cables, etc. Any reduction in voltage means increased current on load, and reduction in torque capacity, as the square of the voltage, both at starting and on load. This reduction in torque may be excessive at starting, when the current is usually higher than on load.

Motor Size

Under certain conditions of ambient temperature, etc., as defined in B.S. 2613 : 1957, a motor of given size and speed is capable of a certain maximum continuous output. This output, even though for the duty in question it may not apply, provides a useful standard of reference for the motor size, and will be used as such in the following, termed "equivalent output".

The two basic factors determining the size of motor for a given application are the thermal capacity and the torque capacity, under all conditions of loading.

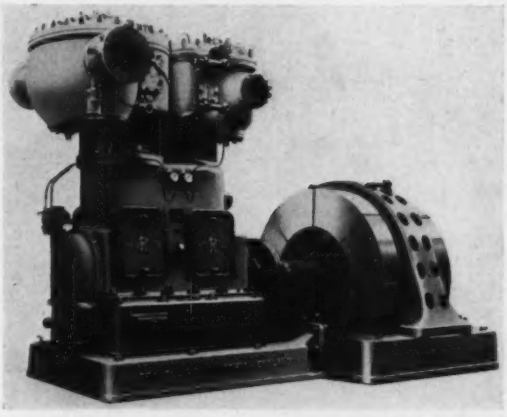
THERMAL CAPACITY—It is normal to assume that the correct equivalent output can be determined by taking the "root mean square" of the load current, and, by extension, the torque. The characteristics, Figs. 1-7, show that this extension is not strictly accurate, as the current is not proportional to the torque, but the assumption is sufficiently accurate between the normal limits for which the calculation is likely to be made, namely about 50 per cent and 150 per cent torque.

This method must be used circumspectly, for two reasons. First, certain windings on the motor (notably excitation windings on synchronous motors and shunt windings on d.c. motors) may have constant current, and hence heating, whatever the load. Second, if the duration of the load approaches the "thermal time constant" of the motor, this being defined as the time taken to reach 63 per cent of the final steady temperature for any fixed load, the temperature may rise above the allowed temperature if a motor based on the root mean square current is used.

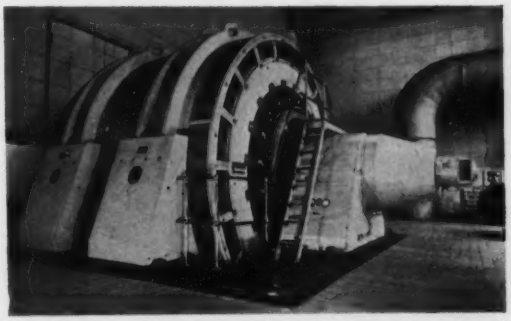
With loads of such duration, a good approximate method (also useful for determining the equivalent output of short-time rated motors) is to use a series of exponential curves as shown in Fig. 8.

In these the horizontal axis represents time, referred to as the thermal time constant of the motor in question. This is about 15 minutes for screen-protected motors up to about 300 h.p., rising thereafter to about 45 minutes for motors of about 5,000 h.p. For totally enclosed fan-cooled motors these times must be increased by about 100 per cent, and for totally enclosed by about 700 per cent.

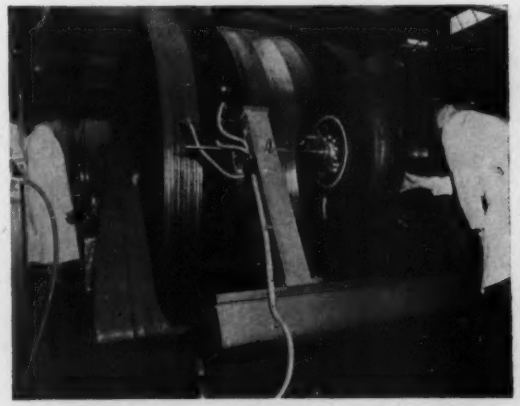
The vertical axis on Fig. 8 represents temperature rise.



This 320-h.p., 323-r.p.m. squirrel-cage induction motor is shown here driving a compressor. Made by Crompton Parkinson, it is started by direct switching.



This B.T-H. 7,000-h.p., double unit, d.c., separately-excited motor drives a 43-in. cogging mill at the Steel, Peech & Tozer works at Sheffield.



An English-Electric 400-h.p., 1,040-r.p.m. d.c. motor with Ward Leonard control driving a brake and tyre testing machine at the Dunlop works at Coventry.

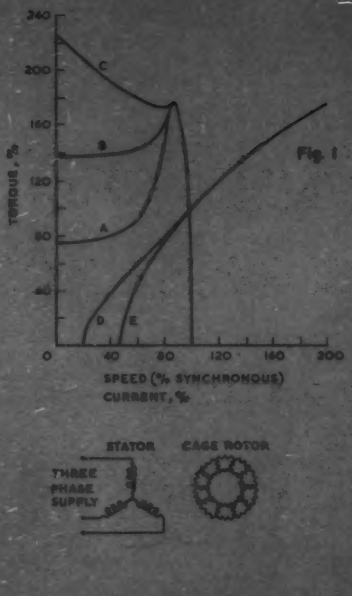


Fig. 1

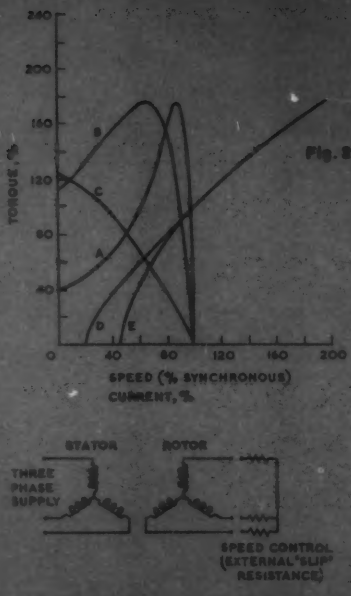


Fig. 2

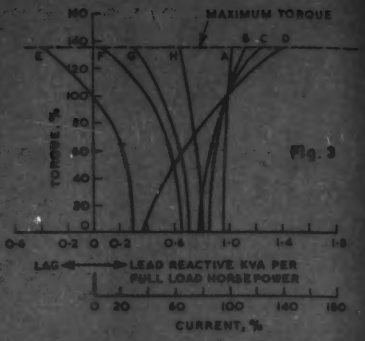
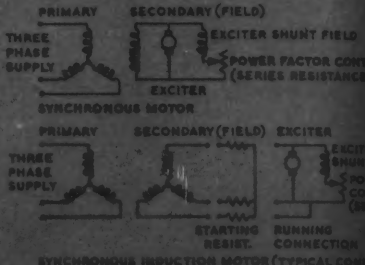


Fig. 3



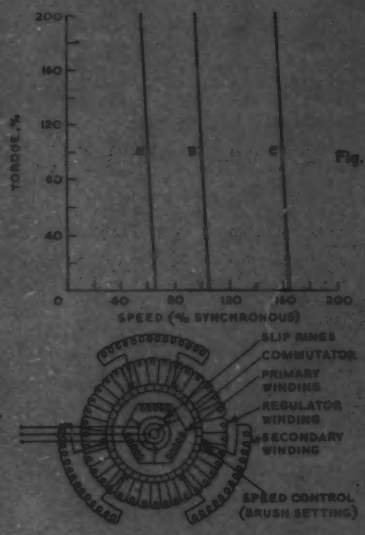


Fig. 4

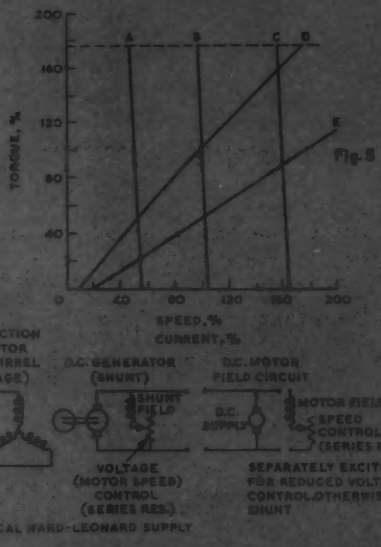
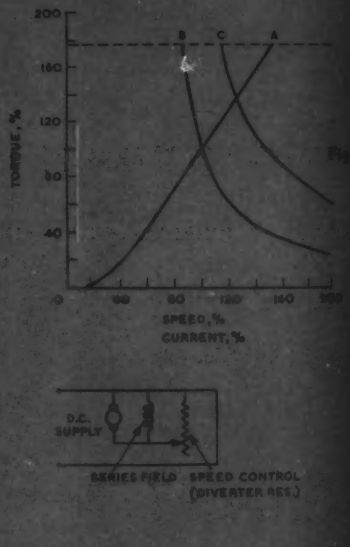


Fig. 5



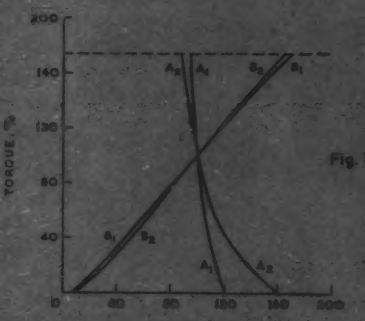
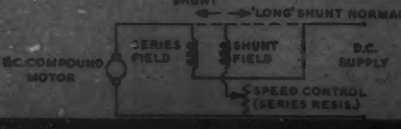


Fig. 7



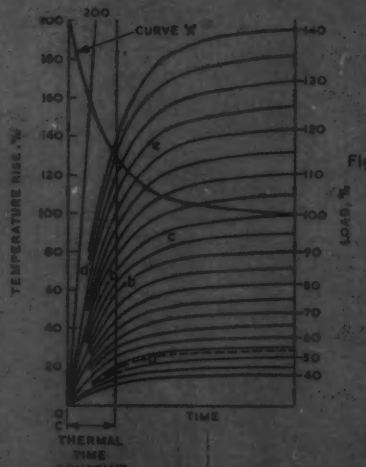


Fig. 8

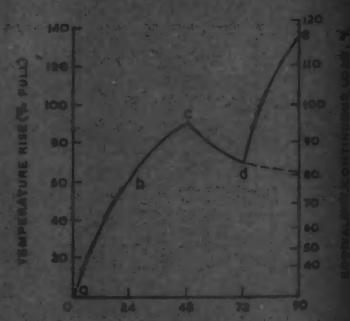


Fig. 1. Squirrel-cage induction motor characteristics (typical).

(A) Standard cage: speed/torque. (B) Special cage: speed/torque. (C) Double cage: speed/torque. (D) Four-pole motor: current/torque. (E) Sixteen-pole motor: current/torque. D and E for standard cage.

Fig. 2. Slipring induction motor characteristics (typical)

(A) Standard motor: speed/torque. (B) Motor with 10 per cent slip resistance: speed/torque. (C) Motor with 66⅔ per cent slip resistance: speed/torque. (D) Four-pole motor: current/torque. (E) Sixteen-pole motor: current/torque. D and E for no slip resistance.

Fig. 3. Synchronous and synchronous induction motor characteristics (typical).

Current/torque curves for motor designed for full load at (A) unity power factor, (B) 0·9 power factor, (C) 0·8 power factor, (D) 0·5 power factor.

Reactive kVA per full load h.p./torque curves for motor designed for full load at (E) unity power factor, (F) 0·9 power factor, (G) 0·8 power factor, (H) 0·5 power factor.

Fig. 4. Schrage motor characteristics (typical).

With brushes set to give (A) 60 per cent synchronous speed at full load, (B) synchronous speed at full load, (C) 160 per cent synchronous speed at full load.

Current/torque curves depend on speed setting, but at synchronous speed are similar to induction motor curves with an increase in light-load current of about 60 per cent. This light-load current will increase with any change, up or down, of speed.

Fig. 5. D.C. shunt motor characteristics (typical).

(A) Speed/torque curve with reduced voltage control. (B) Speed/torque curve at normal speed. (C) Speed/torque curve with reduced field current control. (D) Current/torque curve for A and B. (E) Current/torque curve for C.

Fig. 6. D.C. series motor characteristics (typical).

(A) Torque/current curve. (B) Torque/speed curve. (C) Torque/speed curve with field control by diverter resistance.

Fig. 7. D.C. compound motor (cumulative) characteristics (typical).

(A) Speed/torque curves. (B) Current/torque curves. A_1 and B_1 indicate "light" compound. A_2 and B_2 indicate "heavy" compound.

Fig. 8. Curves for determining motor size, based on thermal capacity, loading and permissible temperature rise.

Fig. 9. Temperature/time curve for example quoted (see text—top of column, right—and relevant lettered sections in Fig. 8).

The right-hand scale shows the percentage continuous load torque (assuming torque is proportional to current) equivalent to the temperature rise on the left-hand scale.

The temperature rises (or falls as shown by curve "A" for an initial temperature of 200 per cent and a load of 100 per cent) to the final steady temperature along an exponential curve which depends on the load and the initial temperature (assuming a fixed ambient temperature) and which has the motor thermal time constant.

As an example of the use of the curves, take a motor running at 730 r.p.m. having consecutive loads, each for 24 minutes, of 180, 200, 160, and 250 h.p., the motor thermal time constant being 20 minutes (i.e., the horizontal scale in Fig. 8 represents 96 minutes), then the root mean square method will give, assuming constant speed, an equivalent output of 200 h.p.

The exponential curves give a temperature/time curve as shown in Fig. 9, relevant sections of Fig. 8 being lettered to match. The maximum temperature is here 136 per cent which is equivalent to a continuous load of about 117 per cent, meaning the correct equivalent output is 234 h.p. Thus the method gives a higher equivalent output than the root mean square method.

The effect of a period of shutdown is to increase the thermal time constant during the period from about three (for small motors) to five (for large motors) times the full speed figure, the increase at speeds between full speed and standstill being proportional to the speed reduction.

TORQUE CAPACITY—The minimum torque capacity as specified in B.S. 2613:1957 is shown in Table 2. The limits are due to reactance, excitation and commutation, for induction motors, synchronous motors and d.c. motors respectively.

Slightly higher torque capacity may tend to be available, notably on induction motors with speeds of 1,000 r.p.m. or more (50 c/s assumed), synchronous motors designed to run at a power factor of 0·9 leading or less, and d.c. motors designed for 220 volts and below (unless this means excessive current).

If the overload torque required by the load (e.g., crushers, presses, shearing machines, etc.) is more than the figure in B.S. 2613 : 1957, the equivalent output must be increased by the ratio of the two torques. It should be noted that the actual torque is to be used, not the overload (e.g., an overload of 75 per cent is a torque of 175 per cent).

A brief high overload can often be partly supplied by a flywheel, rendering it unnecessary to increase the equivalent output for the overload. A flywheel produces torque only when the speed changes, consequently it is usual to have, in the case of induction motors, a slipring motor with a slip resistance in the rotor circuit to give a speed of about 90 per cent synchronous at full load. The duty cycle must be such as to allow the motor to accelerate the flywheel between peak torques.

Flywheels are of little use in the case of synchronous motors except to damp out torque oscillations over one revolution, such as occur with reciprocating compressors.

The necessary size of flywheel can be obtained roughly from the following equations.

$$\frac{(F_h - F)}{(F_h - F_l)} = e^{-kt} \qquad \text{where } k = \frac{1{\cdot}61 \times H \times 10^9}{S \times N_1 \times N \times I}$$

$$\text{and } S = \frac{(N - N_1) \times 100}{N} \quad \text{(per cent slip for an induction motor).}$$

where F = torque supplied by motor (per cent full load).
F_h = high load torque applied (per cent full load).
F_l = initial load torque before the high load torque is applied (per cent full load).
I = total system inertia referred to motor speed (lb. ft.²).
H = motor full load output (h.p.).
N = motor no load speed (r.p.m.).

TABLE 1. Typical electric motor applications

Squirrel Cage Induction Motors

Of robust construction, ideal for high speeds, and often supplied from high-frequency sets. Typical uses are:

Machine tools	Fairly constant speed loads. Built-in units sometimes available.
Textile machines, e.g., carding machines, ring-spinning frames	Rotor heating at starting due to high inertia likely on carding machines.
Portable tools	Often high speeds from high-frequency supply.
Centrifugal pumps and fans	Rotor heating at starting due to high inertia likely.
Recip. compressors	Where off-loading reduces starting torque required.
Conveyors	Sensibly constant speed drives only.
Woodworking routers	Supply at high frequency.

—with multi-speed stators

For use where several discrete speeds rather than a range are required, e.g., drilling machines and machine tools.

—with variable-frequency supply

Limited to drives where a number of motors run in synchronism, starting on the low-frequency setting. Used particularly where mechanical vibration is severe, such as variable-speed roller drives (e.g., run-out tables on rolling mills).

Slipring Induction Motors

Usually for drives where inertia or frequent starting make starting by rotor resistance desirable, if not essential (e.g., heavy lathes, grinders, boring machines, printing machines (platens and flat-bed machines), Banbury mixers in rubber mills, cranes.

—with rotor resistance speed control

Automatic slip regulators may be used to relate the slip to supply current limits. Examples are wheel lathes, where a slow speed setting is required for hard spots in tyre rims (rotor resistance is switched by operator), flywheel machine drives (such as scale breakers and broadside mill drives in steel mills).

—with multi-speed windings and slip resistance speed control

Used for wide speed range to reduce losses in slip resistance at low speeds, e.g., gas compressors.

Synchronous Motors

Generally used where power factor or constant speed is important, e.g., rotary compressors, reciprocating compressors (where off-loading permits), d.c. generators and frequency changers.

Synchronous Induction Motors

For such applications as cement mill rotary kilns or mine fans (where the high starting torque is useful, but trouble may occur with inertia acceleration and synchronising), pumps, constant speed testing machinery, board mill refiner drives and compressors.

Schrage Motors

Used where its small speed regulation at low speeds and high torque for acceleration are required, e.g., machine tools, paper machinery (reelers, cutters, calenders, coaters and driers), mechanised bakery machines (provers, travelling ovens, etc.), cranes, frames handling wool, cotton, flax or silk fibres, knitting machines, rotary printing presses.

D.C. Shunt Motors

For such duty-cycle machines as haulage and tippler equipment.

—with Ward Leonard control

Used where flexible control is required. This system lends itself to "closed loop" control and is thus used where flexible control is wanted, e.g., printing presses, slabbing mills and run-out tables in steel mills, rubber mill calender drives, winder motors, rotating beam drives, gas boosters, paper machinery.

D.C. Series Motors

Have high accelerating torque, maximum speeds of operation on duty cycles. Speed regulation large. Useful for flywheel-assisted motors on fluctuating loads, e.g., traction motors, cranes and handling equipment. *Must not be off-loaded.*

D.C. Compound Motors

High accelerating torque. Useful for high inertia drives. Can be off-loaded. Examples of application: pulverisers, centrifuges, fans and blowers, steel mills (e.g., continuous finishing stands of hot strip mill).

N_l = motor full load speed (r.p.m.).
t = duration of high load torque (seconds).

This assumes that with the load torque at a certain value (F_l) a high torque (F_h) is applied which lasts for t seconds, and, not quite correctly, that the speed drop is proportional to the torque.

Note that if any portion of the load is driven at a different speed from the motor its inertia must be referred to the motor speed by multiplying by the square of the ratio of load speed to motor speed.

POWER FACTOR CORRECTION—To reduce costs due to reactive kVA., individual capacitors are often fitted to induction motors. Their size is usually limited to 85 per cent of the no load kVA., giving a corrected power factor of about 0·92-0·98 (on many motors about 0·95, normally also the economic optimum).

TABLE 2. Minimum torque capacity of electric motors

Type of Machine	% Excess Torque for 15 sec.
D.C. motors	
Short time rated irrespective of h.p.	100
Continuous maximum rated up to and including 50 h.p.	100
Continuous maximum rated above 50 h.p. up to and including 150 h.p.	75
Continuous maximum rated above 150 h.p.	50
A.C. induction motors	
Short time rated irrespective of h.p.	100
Continuous maximum rated up to and including 50 h.p.	100
Continuous maximum rated above 50 h.p. up to and including 500 h.p.	75
Continuous maximum rated above 500 h.p.	60
Synchronous (salient pole) motors	50
Synchronous induction motors	35

Synchronous motors designed for a leading power factor can be used to correct the system power factor by taking leading reactive kVA. (see Fig. 3). The amount of correction cannot be calculated without knowing the system power factor and kVA.

Rough power factor calculations can be made with the nomogram in Fig. 10.

Speed Control

For any motor controlled by any method it is imperative that the relationship between the load speed and load torque be known when estimating the equivalent output.

Squirrel cage induction motors can be controlled by frequency variation (usually only for a number in synchronism as in rolling mills). Two or three speed windings may be used, with increased equivalent output to suit.

Slipring motors can be controlled by rotor resistance down to about 30 per cent synchronous speed at full load torque, but this is extremely wasteful of power (in the rotor resistance), and will mean a large motor due to the rotor iron losses and the reduced cooling at the lower speed.

The speed of the Schrage motor can be set, over a wide range, by the brush position. The normal range of 50-150 per cent synchronous speed (size limited to about 70 h.p. per pair of poles) can be extended to 20-200 per cent synchronous speed by suitable design.

The d.c. shunt motor speed can be controlled over a range of about 100-400 per cent by shunt field control. By variation of the armature voltage, reduced speeds can be obtained down to about 10 per cent, by supply from a separate motor generator set (Ward Leonard), or lower if a booster be added to this or a grid-controlled rectifier used. This latter means an increase in equivalent output, due to ripple, of about 15-20 per cent. Motors with such reduced voltage speed control are properly designated separately excited, but for convenience are usually grouped with shunt motors.

The speed of a series motor can be controlled down to

about 10 per cent by an armature divertor resistance (a method wasteful of power), or up to the mechanical limit by a field divertor resistance (wide variation of speed will occur with load). If operation at no load is possible a shunt limiting winding should be used to keep the speed down to a safe value.

The compound motor will behave and be controlled as a shunt motor if it has a "light" series, but if controlled by shunt regulation will have wide speed variation with load at high speeds.

The reduced cooling at lower speeds must be considered when determining the equivalent output, and for very low speeds will necessitate blowers.

Induction and synchronous motors can be reversed by reversing two phases, the Schrage motor by brush adjustment or a special winding, and d.c. motors by reversing either armature or shunt and series windings.

On all d.c. machines, including synchronous motor exciters, on which reversing is required, it is important that the brushes be set in the neutral position.

Starting

At any instant during the starting period part of the motor torque is being used to overcome the load torque and part to accelerate the inertia.

The time taken to accelerate the inertia is given by:

$$t = \frac{0{\cdot}62 \times N_1^2 \times I}{H \times F_a \times 10^4},$$

where t = accelerating time (seconds).
N_1 = motor full load speed (r.p.m.).
I = total system inertia referred to motor speed (lb. ft.^{2}).
H = motor full load output (horsepower).
F_a = mean accelerating torque (per cent full load).

The normal squirrel cage induction motor has a starting torque of about 50-100 per cent, and a starting current of about 500-600 per cent. By special rotor design, giving reduced efficiency and power factor at full load, the torque can (with about 25 per cent increase in equivalent output) be increased to 300 per cent with about 500 per cent current or 200 per cent with about 350 per cent current.

To reduce the starting current, reduced voltage starting such as star/delta (not recommended for motors above about 250 h.p.) or auto transformer can be used, the motor inherent starting current and torque being reduced as the square of the voltage.

A squirrel cage induction motor accelerating a large inertia has unavoidable heavy losses in the rotor, the heating being almost independent of starting torque, and a general limitation is that the accelerating time, assuming full load accelerating torque is available, shall not exceed 20 seconds. The limiting inertia is therefore given by putting $t = 20$ and $F_a = 100$ in the acceleration equation.

Any torque up to almost the maximum overload torque can be obtained on starting the slipring motor by switching the motor direct on to the line with starting resistance in the rotor circuit, cutting this out as the motor accelerates. The rotor losses due to the load inertia, which cause cage heating in the squirrel cage type, are here mostly dissipated in the starting resistances. The starting current will be about 1·25 times the starting torque, as a percentage (e.g., 100 per cent torque will require about 125 per cent current).

The starting torque of the synchronous motor tends to be low and the starting current high, since it starts on its damping winding, this being a relatively inefficient squirrel cage (unless specially designed).

The synchronous induction motor starts as a slipring motor, the maximum starting torque varying from about twice full load for high-speed motors, to full load for low-speed motors.

In the case of synchronous and synchronous induction motors with a high inertia load there is the added problem of synchronising; the maximum inertia against which a typical synchronous induction motor will synchronise is given by the following very approximate equation:

$$I = \frac{4{\cdot}8 \times H^{1{\cdot}5} \times 10^8}{N_1^{1{\cdot}5} \times P^2 \times F_s^2},$$

where I = total system inertia referred to motor speed (lb. ft.^{2}).
H = motor full load output (horsepower).
N_1 = motor full load speed (r.p.m.).
P = motor full load power factor.
F_s = torque against which motor must synchronise (per cent full load).

The Schrage motor, to take a typical example of it, will give about 150 per cent torque with 175 per cent current when started with the brushes set at the designed minimum speed of 30 per cent full speed. A motor designed for a high minimum speed may need secondary resistance to give adequate starting torque and/or limit the starting current.

D.C. motors of all types are normally started by inserting series resistance, this method giving, as typical figures, 200 per cent torque with 250 per cent current for shunt motors, 250 per cent torque with 220 per cent current for series motors, and either, for example, 200 per cent torque with 190 per cent current for "light" compound motors, or 250 per cent torque with 240 per cent current for "heavy" compound motors. Motors having reduced voltage-speed

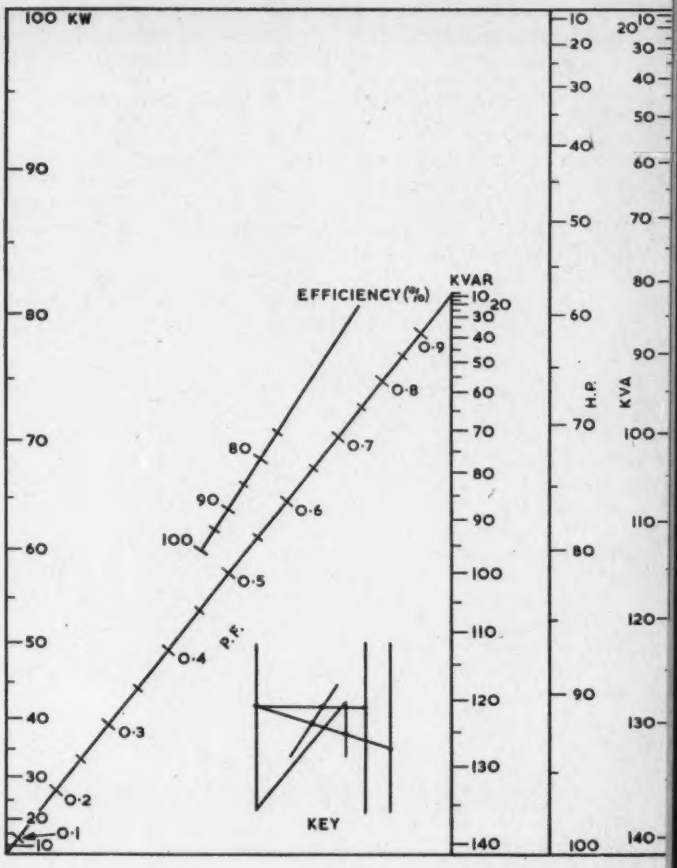


Fig. 10. Nomogram for calculation of power factor correction from the system power factor and kVA.

control (such as Ward Leonard) may be started on the low-speed setting. The only limiting factor with high inertia loads is that the thermal capacity of the motor shall be adequate for the starting duty.

Braking

Most types may be braked by "plugging", or reversing one or more of the windings in order to reverse the torque. If this system is used on squirrel cage motors the limiting inertia is about one-third of that for starting. In some cases added resistances, as at starting (which this type of braking closely resembles) are used to give a high torque or to limit the current. This type of braking gives a mean braking torque of about 80-90 per cent of the maximum starting torque if required, but the motor will commence to run up in the opposite direction unless some form of relay is used to prevent this. The windings may have to be braced to stand the mechanical forces imposed.

Another method is dynamic braking, by exciting one winding from a d.c. source (with a synchronous motor it is usual to have a separate motor exciter set which continues to run and supply the field, sometimes with increased current, during braking) and loading the other winding on to a resistance load, giving a mean braking torque of about 100-150 per cent (the type of motor makes little difference except that commutation tends to limit it to about 100 per cent on d.c. motors).

The Schrage motor can be braked by running the brushes down to the lowest speed setting, giving a mean braking torque of about 150 per cent.

The braking time will be given by the same equation as the accelerating time at starting, bearing in mind that any mechanical braking torque must be related to the motor full load torque and added to the mean motor braking torque before the calculation is made.

It may be necessary to know the number of revolutions the motor makes before standstill, and this can be estimated by assuming a mean speed of half the initial speed for "plugging" or, due to fall away of torque at low speeds, one-third of the initial speed for dynamic braking.

Conclusion

Much has been left out of this article of necessity, since the subject is extremely wide, but a much wider range of motors and duties can be found in a publication of the British Electrical Development Association.[1]

It must be pointed out that many of the equations and methods herein are only approximate, and the fullest information should be given to the motor manufacturer to enable him to make accurate calculations in a specific case. Facts and assumptions should be clearly differentiated.

The author wishes to express his thanks to the directors of Crompton Parkinson Ltd. for permission to publish this article, and to his colleagues for their assistance.

REFERENCES
1. "Electric Motors and Controls", Publ. No. 3 of *Electricity and Productivity*. British Electrical Development Association.
2. E. R. Laithwaite, "Electrical Variable-Speed Drives", *The Engineers Digest* (Survey No. 3).
3. G. C. Morris, "Duty Cycle Motor Selection", *Electrical Manufacturing*, Nov. 1959.

SEARCHING FOR NEW DIELECTRIC MATERIALS

THE National Bureau of Standards in the U.S.A. is conducting a programme of fundamental research primarily to explain observed dielectric phenomena and to develop theories which can be used to predict the behaviour of certain materials.

To study materials that pass from liquid to solid form in the temperature range of interest, a "fusion cell" has been designed. This is similar to other holders, but allows the material in liquid phase to be held in the space between and around the electrodes. It applies pressure to the movable electrode as the sample is solidifying, thus preventing voids from forming as the material contracts. Work is now under way to determine the effects of solidification on the electrical properties of materials such as dinitropropane, an interesting and nearly spherical molecule that undergoes rotation in the solid state.

To study materials as they make a transition from gaseous dielectric behaviour to liquid dielectric behaviour, resonant cavities for compressed gases have been developed. Studies made with these show that liquid-like behaviour can set in at pressures of less than an atmosphere for the strong dipolar gases. Further work is being initiated which will determine dielectric losses of very low loss gases, as, for example, sulphur hexafluoride which very closely approximates a spherical molecule.

All experimental work is supported by active theoretical studies, some of which are dipole relaxation in molecular crystals, the dielectric properties of semi-crystalline polymers, and the nature of the glassy state.

The study of crystalline non-metallic inorganic solids presents somewhat different problems, both theoretical and empirical, as compared with polymeric materials, where it is desirable to consider the polarisation, in terms of molecular structure. Contributions to the dielectric constant in crystalline non-metallic solids arise from electron displacement, local displacements of the nuclei forming the lattice, and migrations of these nuclei to other sites. These contributions will be affected not only by the crystal structure and orientation, but also by crystalline defects such as impurities, vacancies and domain boundaries.

As ceramic materials are especially sensitive to temperature and humidity fluctuations, studies must be carried out in a controlled environment.

Through continuous efforts to improve accuracy and reliability, it is hoped that eventually the complete relationship between the composition and electrical characteristics of ceramics can be worked out.

While ceramics are crystalline by definition, many polymers are neither completely crystalline nor completely amorphous. Therefore, to obtain a comprehensive picture of these materials, it is necessary to determine the degree of crystallinity as a function of such variables as temperatures and previous history. The degree of crystallinity is related in a simple manner to the density of the polymer.

Theoretical studies which are being conducted to explain the relationship between the electrical properties, the amount of crystallinity and the effects of temperature will form a prominent part of the dielectrics programme on semi-crystalline polymers for some time in the future.

Several factors enter into the reliability of a solid as a dielectric standard. First of all, for a material to be suitable as a standard it must be uniform, another important consideration being the influence of environment factors on the stability of electrical properties. The most promising materials are those whose electrical properties are not greatly affected by the humidity. Humidity studies are presently under way on polymethyl-methacrylate, polystyrene and fused quartz to determine their suitability.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

Increased Efficiency in Camera Shutter

THE Graflex super speed graphic camera is claimed to have a between-the-lens shutter which enables high-speed pictures to be taken with complete uniformity of exposure and without the limitations normally associated with focal plane shutters. In addition to achieving a top speed of 1/1,000th of a second, an increase of 20 per cent in shutter efficiency is claimed, without any of the refinements of an ordinary shutter being sacrificed (see diagram, below left).

The two mechanism diagrams illustrate how the shutter works. In the exploded view (*below centre*) it will be seen that there are four shutter leaves, each being driven by its own pinion and eccentric. For clarity the drawing only shows a single leaf. Four pinions (6) rotate on fixed pivots (2) and are driven by a single ring gear (8). Attached to each pinion (6) is an eccentric (7) which rotates within a bearing attached to each leaf (4). Attached to the leaf bearing is a guide pin (5) which moves in a curved guide slot (3). Movement of the shutter leaf (4) is controlled by the action of the eccentric (7) and the guide pin (5) in the curved guide slot (3). This controlled movement causes the leaf to follow an elliptical path.

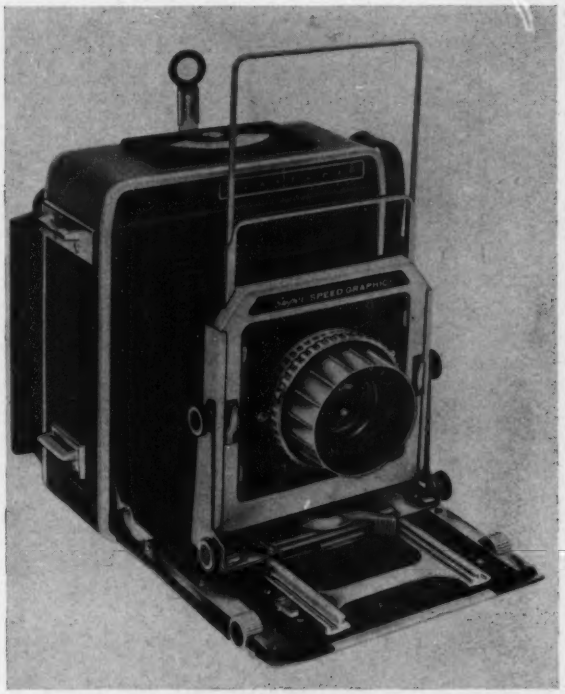
In the schematic drawing of leaf movement, a complete opening and closing cycle are shown, again of a single leaf only:

(A) The leaf is shown in the fully closed position.

(B) The "run-up" phase of the leaf movement, which accounts for the first 86 deg. rotation of the eccentric (7) and drive mechanism, is completed. The leaf (4) is just beginning to open as the eccentric (7) continues to rotate counter-clockwise about the pinion pivot (2).

(C) The leaf (4) is fully clear of the aperture. As the eccentric (7) continues to rotate through 40 deg. the leaf slows down, "rounds the bend" and speeds up for the return stroke. This is the "dwell" phase of the leaf movement, during which the aperture is fully open and is controlled by the timing mechanism.

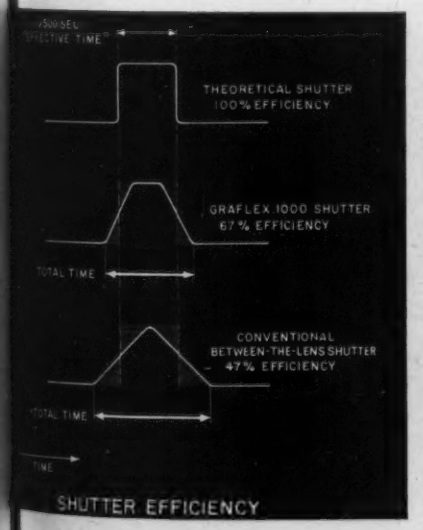
(D) The aperture is completely closed and braking action starts. The eccentric (7) continues to rotate through a full 64 deg., during which time leaf motion is braked to a gentle stop.

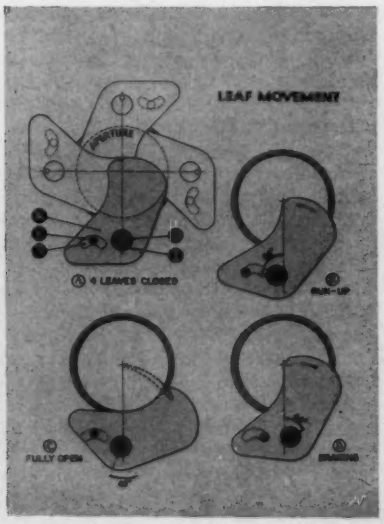


The elliptical movement described, having accelerating and braking phases, is claimed to minimise shutter vibration and subsequent damage to components, and therefore to prolong shutter life.

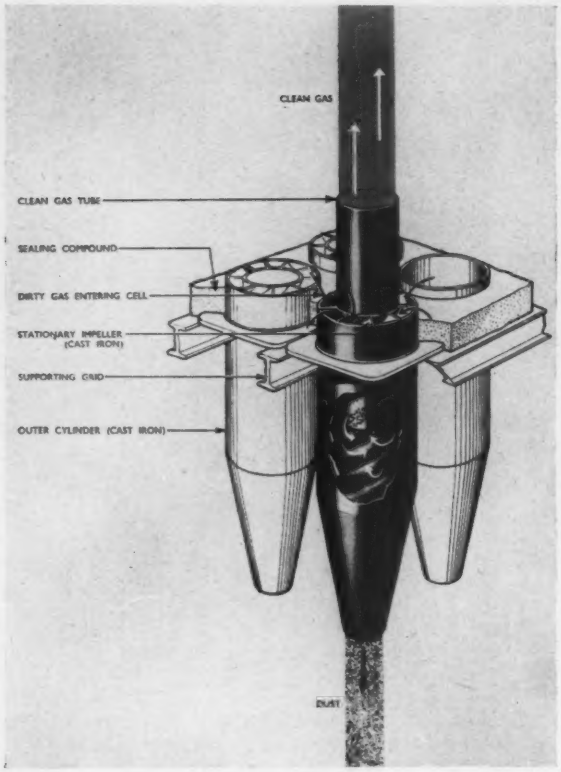
Another feature of the shutter is that the press focus lever which opens and closes both shutter and diaphragm leaves in one operation with the shutter in either the cocked or released position without disturbing prior diaphragm or shutter settings.

The shutter is cocked by turning the non-reciprocating integral lens shade-filter holder. This eliminates external moving parts that often interfere with shutter operation.





Dedusting Plant uses Centrifugal Principle



THE type UK reverse flow Holmes-Rothemule multi-cell cyclone dust collector is considered by the manufacturers to be particularly suitable for those applications where good gas distribution conditions cannot economically be achieved with large gas volumes.

The collector comprises an assembly of cyclone cells, the number of which is directly proportional to the volume of gas to be cleaned. Each cyclone cell consists of two concentric tubes : an outer dirty gas cylinder with a stationary impeller fixed at the inlet and an inner clean gas tube which passes up through the centre of the impeller. The outer cylinder is approximately 10 in. in diameter except at the base, which is conical in shape. The high separating efficiency of the collector is derived from the relatively small diameter of the individual cyclone cells.

The individual cells are supported in a sheet steel grid, which is in turn enclosed in a rectangular steel casing, the lower half of which serves as the dust bunker. In the upper half of the casing, known as the top box, the clean gas tubes terminate in a stepped floor, the construction of which facilitates the removal of individual cells for inspection and maintenance. To ensure that entering dirty gas does not by-pass the cells, gas-tight joints are made on the supporting grid with a special sealing compound.

In operation the impeller imparts an intense swirl to the dust-laden gas as it enters the cell, causing it to descend with a spiral motion. Near the apex of the conical section of the dirty gas cylinder the axial velocity of the spiralling gas is turned through 180 deg. The dust-free gas, having reversed direction, passes up through the clean gas tube to the exhaust fan and stack. The reversal of direction of flow causes the dust to be centrifuged, and it is propelled downwards into the dust bunker.

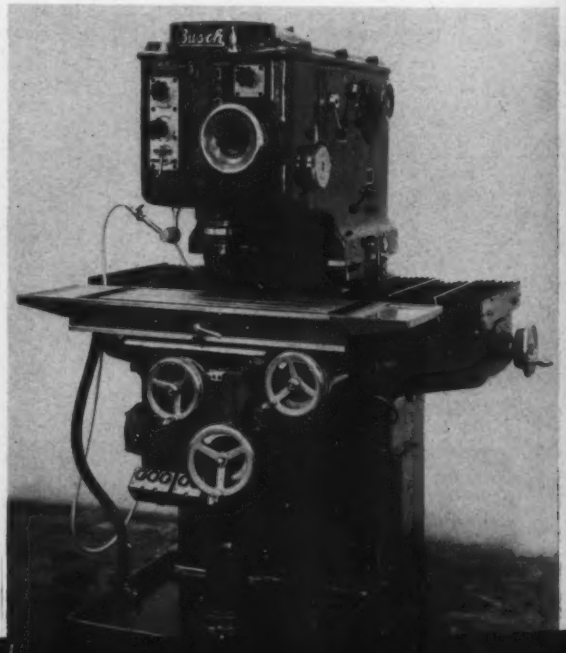
Unusual Hydraulically Controlled Milling Machine

THE Busch FSV5 vertical milling machine is unusual in that the cutter head can make reciprocating movements either longitudinally or transversely, or it can combine these two movements and perform a continuous rectangular movement. In addition, automatic down-feed can be applied to the cutter at each end of the stroke when reciprocating longitudinally or transversely, or at each of two diagonally opposite points when travelling on a rectangular path. On the cutter reaching the predetermined depth the down-feed motion is tripped.

The cross motion is claimed to work with such precision that over the width of the work an I.S.A. class-H7 fit can be obtained regardless of the diameter of the cutter in use. In addition to an intermittent down-feed motion the cutter spindle can also be given a continuous down-feed for drilling purposes. All feed rates are steplessly variable under hydraulic control.

In addition to the movements that can be accomplished by the head, the table also can be moved lengthwise, crosswise and vertically by hand, and is also furnished with an electrically-driven fast elevating motion. Separate electric motors for driving the cutter spindle, the hydraulic pump and for the table-raising motions are of 4, 1·1 and 0·5 h.p. respectively. The working surface measures 13¾ × 35½ in. The vertical traverse of the table is 11¾ in., the longitudinal traverse is 15¾ in., and the cross traverse is 11¾ in.

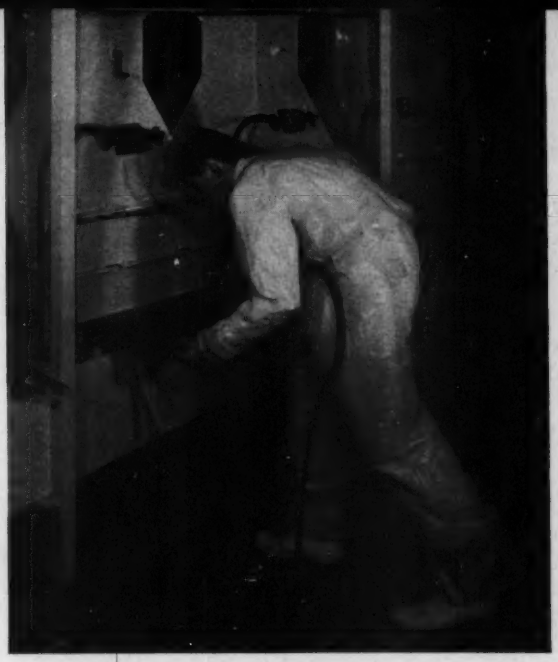
The maximum longitudinal traverse is 22 in. and the hydraulic cross traverse is 0·008-5⅞ in. Feed rates are from ¾-39½ in./min.



HOW INDUSTRY CAN USE BERYLLIUM

Second of two articles on its current applications in general engineering. Here the author discusses the physical properties of the metal and the special handling techniques employed in its fabrication

by N. A. HILL, B.Sc.*



Protective clothing worn by operators handling beryllium sheet. (G.E.C. photograph).

FINELY divided beryllium and its compounds have been reported to be toxic, and the following recommendations of the U.S. Atomic Energy Commission have been found effective in preventing any hazard to health[1]:

(a) The average concentration in the working atmosphere throughout an 8-hr. working day should be less than 2 μgm./cu. m.

(b) A concentration of 25 μgm./cu. m. should not be exceeded, even for extremely short periods.

Although the maintenance of these levels demands stringent precautions, good design of powder handling areas and ventilation systems should avoid undue slowing down of operations. Where beryllium is heated above 600 deg. C. in air, the provision of adequate local extract is advisable to prevent the dispersion of fine oxide particles.

* *Metallurgy division, A.E.R.E., Harwell.*

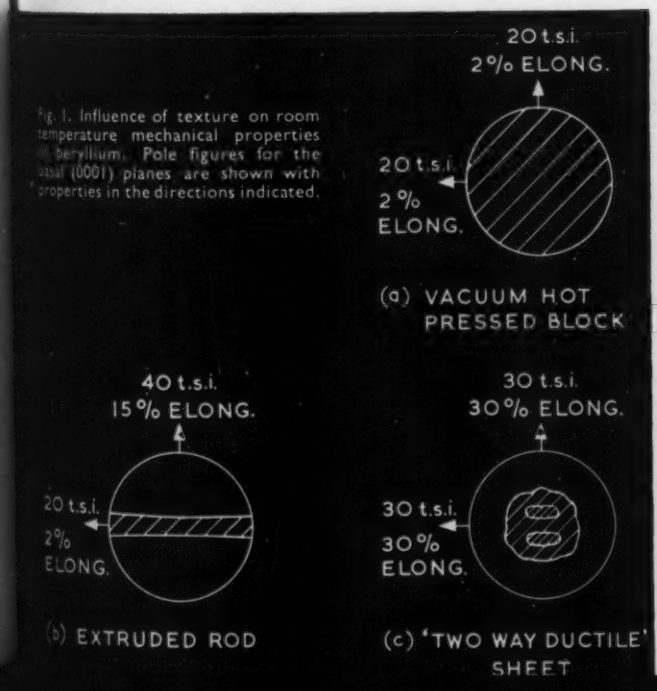


Fig. 1. Influence of texture on room temperature mechanical properties of beryllium. Pole figures for the basal (0001) planes are shown with properties in the directions indicated.

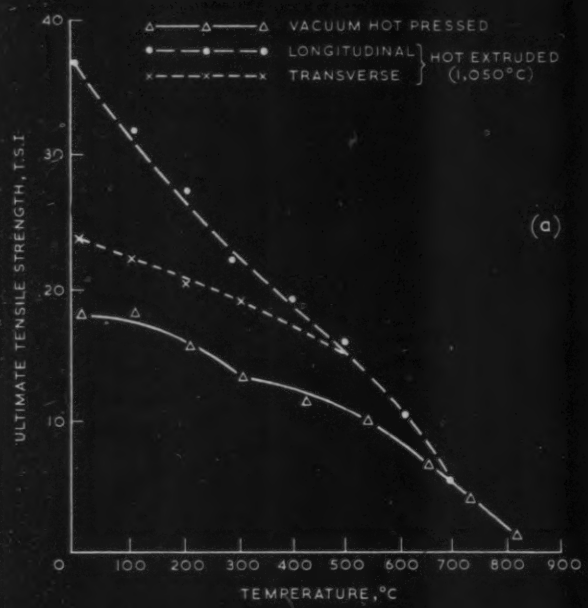
The use of well-ventilated fume cupboards and presses is essential when powder beryllium is being handled, and care is necessary in the design of fume cupboards to prevent eddies of air which could blow toxic quantities of powder out into the general room atmosphere. The use of a glove box avoids this possibility, but does slow operations considerably.

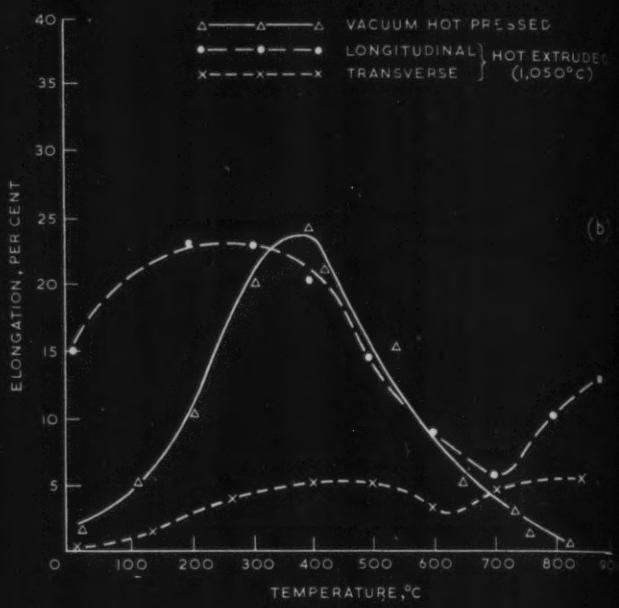
The maintenance of safe levels during machining is possible by various means. By careful attention to design,[2] high-velocity extract tubes can be used to ensure that every particle is sucked away immediately it is formed. The cost of sufficiently powerful and effective fans and filters is considerable, but where large quantities of beryllium are being handled this is repaid, as swarf is collected in a form which can be easily re-cycled. Enclosing the machine in a glove box is possible, although this restricts the freedom of operation and necessitates occasional stoppages for cleaning; there is, however, no need for a very high-powered dust extraction system. A simpler method suitable for working on a small scale is wet machining using a drip feed of heavy oil to cut down dust and a local extract to remove any which escapes or any fine oil spray. Careful use of any of these three methods will result in safe working. Periodic air samples must be analysed for beryllium content, and frequent samples on new or non-routine operations are advisable so that a safe method may be established as quickly as possible. If any hazard is suspected, the use of respirators and protective clothing is advisable.

Laboratories handling beryllium provide complete changes of clothing for all operatives, a complete general ventilation system, and shower facilities to encourage cleanliness.

Strength and Brittleness

Tensile tests on cast beryllium have shown strengths of up to 10 t.s.i. and zero elongation, but the extrusion of cast billet has produced rods with ultimate tensile strengths of 20-25 t.s.i. and elongations of 2-3 per cent. With the wide use of powder metallurgy, striking advances have been made in the production of partly ductile beryllium. Tensile strengths range from 20-45 t.s.i. and elongations from 2-40 per cent at fracture. The differences are





dependent both on fabrication methods and direction of testing.

In mechanical testing of beryllium up to 300 deg. C. it has been found that the best results are obtained consistently only when the specimen surface has been removed by etching, and removal of 0·005-0·010 in. of metal from each surface has been recommended. The reason for the improvement in properties has not yet been clearly explained, but electron micrographs[3] have indicated fine cracks 0·003 in. deep in the surface of machined beryllium. Thus, when assessing the room temperature properties of beryllium, it must be remembered that quoted figures can only be realised with suitably prepared specimens.

Isotropic hot-pressed beryllium powder has a tensile strength of 20-25 t.s.i. and an elongation of 1-3 per cent.[4] Extrusion or rolling introduces pronounced textures and a marked improvement in properties parallel to the direction of elongation during working. Thus extruded rod possesses an ultimate tensile strength of 40-45 t.s.i., and an elongation of 15-25 per cent.[5, 6] The effects of texture are illustrated by Fig. 1, where it is seen that the best mechanical properties are developed in directions parallel to the basal planes. In "two-way ductile" sheet, all the basal planes are parallel to the sheet surface and elongations of 30-50 per cent with tensile strengths in the range 30-35 t.s.i. are achieved.[7] However, although the best tensile results on beryllium are encouraging, true ductility has not yet been realised, for attempts to bend strips of two-way ductile sheet are only successful when the specimen width is less than three times the sheet thickness, and when 0·008 in. of metal has been etched from all surfaces.[8] Attempts to bend wide or unetched strips result in brittle fracture before any measurable bend has occurred.

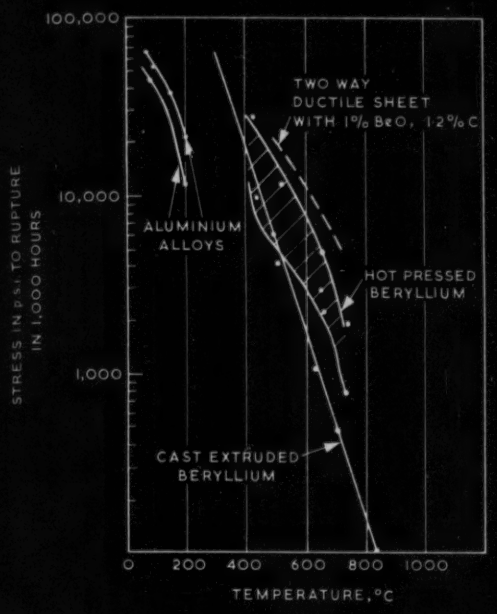
A wide range of room-temperature tensile properties can be achieved with beryllium by attention to fabrication details, and the best tensile results compare with other metals; but beryllium is still extremely brittle under complex stresses and no way of overcoming this extreme room temperature brittleness has been suggested. There are still conflicting views as to its cause: on the one hand, the fundamental properties of the beryllium lattice are thought to prohibit deformation,[9] and on the other hand there is the possibility that really pure beryllium might be ductile. However, there is no method available for reducing the oxygen content of beryllium to a few parts per million and, until beryllium of very high purity is isolated, the question will remain open. The only present course available is to avoid any possibility of triaxial overstressing occurring in beryllium used for structural purposes, i.e., to "design out" the inherent brittleness, but this does not remove the suspicion that under fault conditions beryllium might well fracture extremely suddenly where other metals would yield to accommodate overstressing by plastic strain.

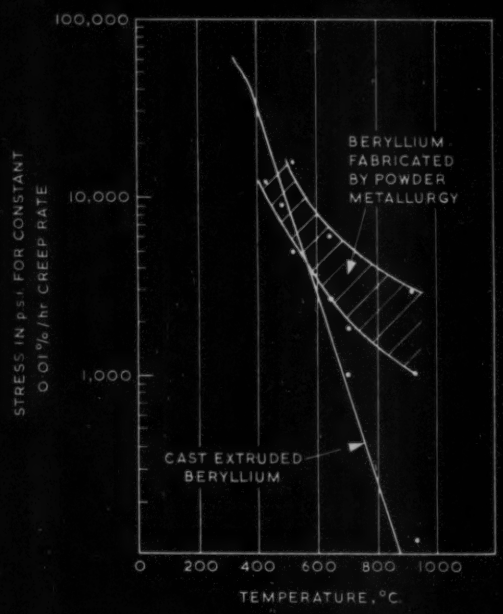
The modulus of elasticity of beryllium is unusually high and lies between 41×10^6 and 45×10^6 p.s.i.[4] This rigidity at room temperature is one of the outstanding advantages for structural uses when it is remembered that beryllium has a density of only 1·84 gm./c.c.: here are two properties which should ensure an increasing demand for the metal.

The room-temperature properties of a variety of beryllium types are summarised in Table 2.

Strength at Elevated Temperatures

Short-time tensile tests have been carried out at temperatures up to 800 deg. C.[4, 10, 11] on beryllium fabricated by widely differing methods; the results are plotted in Fig. 2. As might be expected, ultimate strength values decrease with increasing temperature, and the higher the room temperature strength, the more rapid is this decrease, so that, at 800 deg. C., all types of beryllium fail in tension at between ½ and 1 t.s.i. Tensile elongation to fracture for all the materials increases from room temperature to reach a peak between 300 deg. C. and 500 deg. C., although the improvement in specimens transverse to the working direction is relatively slight. There is a double peak at 400 deg. C. and 800 deg. C. for elongation of cast and extruded materials tested parallel to the extrusion direction, but no conclusive explanation of this has been offered. Examination of fractures has shown that for powder products the fracture mechanism changes from transcrystalline to intercrystalline over the range 400-600 deg. C., while the same change in cast products occurs over the range 300-600 deg. C. Variations in strain rate, particle size and oxide content have been shown to affect the tensile proper-





ties of hot-pressed beryllium at elevated temperatures. Variations in these may thus be used to control the properties in tensile testing to a desired level.

Stress rupture and creep results have been presented in various different ways using many grades of beryllium and different testing procedures, so that detailed comparison of results is not possible.

A general curve for stress rupture is presented in Fig. 3; the stress to cause rupture in 1,000 hr. is plotted against temperature. The weakest material is extruded cast bar[10] and the strongest is two-way ductile sheet containing 1 per cent BeO and 1·2 per cent C[12]; hot-pressed beryllium containing 1 per cent, 2 per cent and 3 per cent BeO and normal two-day ductile sheet fall between the two. There is a noticeable improvement in the resistance to rupture with the addition of 1 per cent carbon to two-way ductile sheet, and this indicates that further research will probably raise the stress-rupture strength of beryllium considerably without undue increase in density or neutron capture cross-section.

The stresses which produce a constant 0.01 per cent/hr. creep rate in fabricated beryllium are plotted against temperature in Fig. 4. All the powder beryllium products[4, 13] show an improvement over cast and extruded metal.[10] Increasing oxide content also improves the resistance to creep. The development of beryllium with a considerably higher creep resistance should be possible, but it is likely to be expensive and may not be undertaken until available metal has been fully tested in service.

The modulus of elasticity[4] of beryllium in tension and compression is plotted against temperature in Fig. 5. There is a very little decrease in stiffness up to 450 deg. C., but above this there is a very rapid fall so that structural applications for beryllium as it is now available are limited to temperatures not exceeding 500 deg. C. At this temperature and below it is without doubt an outstanding structural material where strength must be coupled with lightness.

The major problems of manufacturing and fabricating fully dense beryllium have been solved, but joining and brittleness remain as outstanding difficulties which, at the present time, are being circumvented rather than solved. Beryllium is being used in a variety of forms from X-ray windows a few thousandths of an inch thick to moderator blocks up to 6 ft. long. These uses will increase in the future and the call for lighter and higher strength structural materials is likely to result in demands for comparatively large quantities of beryllium. Over the last fourteen years

TABLE 1. Physical properties of beryllium

Density:	1·85 gm./c.c.
Melting point:	1,283°C
Boiling point:	2,970°C.
Vapour pressure:	$\log_{10}P(\text{atm.}) = 6{\cdot}186 + 1{\cdot}454 \times 10^{-4}T - \frac{16{,}700}{T}$
Thermal neutron cross-section:	0·0090 ± 0·0005 barns/atom
Electrical conductivity:	40% I.A.C.S.
Velocity of sound:	12,600 metres/sec.
Crystallography:	Hexagonal close packed $a_0 = 2{\cdot}285$ Å. $c_0 = 3{\cdot}583$ Å.
Thermal expansion:	25—100°C. 12×10^{-6} in./in./°C. 25—1,000°C 18×10^{-6} in./in./°C.

TABLE 2. Range of room temperature mechanical properties of beryllium

	Ultimate Tensile Strength t.s.i.	% Elongation at Fracture
Vacuum cast billet	10	0
Vacuum cast billet Extruded (longitudinal)	20–25	2–3
Hot pressed powder	20-25	1–3
Extruded powder: longitudinal	40–50	12–25
cross dir.	20	1
Uni-directionally rolled powder: longitudinal	40	10–15
cross dir.	20	1
Bi-directionally rolled powder	30	20–30
Cross-rolled extruded flat	26–35	25–50

Above. Typical products produced from beryllium.

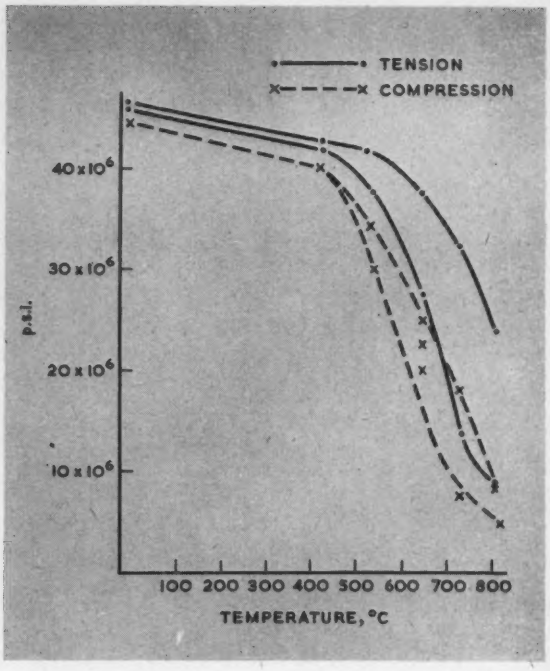


Fig. 5. Modulus of elasticity of beryllium[28].

the tensile strength of beryllium at room temperature has been raised from 10 t.s.i. to 45 t.s.i. and the elongation from zero to 40 per cent, while at 600 deg. C. creep strengths have been raised by a factor of three and stress rupture resistance by a factor of five. It is not likely that progress over the next few years will be so spectacular, but the possible attainment of true triaxial ductility provides a great stimulus to research into better refining and fabrication methods, and also to a better understanding of the fundamental properties of the metal.

REFERENCES

1. A. M. A. Hardy, *Arch. Indust. Health*, 1955, **12**, p. 179.
2. M. Eisenbud, *The Metal Beryllium*, Chap. 12A, A.S.M., 1955.
3. D. R. Walker, *Mechanical Engineering*, 1958, **80**, p. 57.
4. R. G. O'Rourke *et al.* U.S.A.E.C. Report 1956. COO-312.
5. J. L. Klein, V. Macres, D. Woodward and J. Greenspan, Chap. 7D, *The Metal Beryllium*, A.S.M., 1955.
6. J. Williams, W. Munro and J. Jones, A.E.R.E. Report 1955. M/R 1679.
7. J. Greenspan, U.S.A.E.C. Report 1957, NM1-1174.
8. N. A. Hill, A.E.R.E. Memo. 1958, M/M 193.
9. S. F. Pugh, A.E.R.E. Report 1954, M/R 1290.
10. A. R. Kaufmann, P. Gordon and D. W. Lillie. *Trans. A.S.M.*, 1950, **42**, p. 785.
11. W. W. Beaver and K. G. Wikle. *Trans. A.I.M.E.* 1954, **200**, p. 559.
12. J. Greenspan, U.S.A.E.C. Report 1956, TID-7526, part 1.
13. J. Williams, *Metallurgical Review*, 1958, **3**, p. 1.

JOINING METHODS FOR PLASTICS-COATED STEEL

THERE is considerable scope for plastics-coated steel where corrosion resistance rather than decoration is the principal aim. Two methods of fabrication are used: hot-gas welding and high-frequency techniques. The hot-gas method is very similar to gas welding of metals, using a welding rod of p.v.c. It is possible for the average operator to carry out butt, overlap and flange joints satisfactorily, but in some cases an adhesive can be used to help in the welding process. Welding speed varies from one operator to another, but a good, neat joint is usually possible at a speed of 4 in. per min.

High-frequency welding is accomplished with heat and pressure and produces welds similar to seam welds in metals. At the present time the size of component to be welded has an important bearing on the success of the method in particular applications.

Resistance welding is by far the most successful method of joining plastics-coated steel parts; the presence of the plastics has made necessary the development of welders with both electrodes on the same side of the strip. A variation of this is magnetic force welding, utilising a solenoid for the follow-up forging action after the initial melting. The build up of force is controlled in time so that although the projections are not seriously deformed by electrode pressure before melting adequate follow-up forging action occurs. The method is claimed to give superior welds with no marking of the p.v.c., but it is not yet widely applied in this country.

Argon-arc spot welding also has limited possibilities where a marked surface on the p.v.c. is permissible. Stud welding techniques, especially using the "fusible pip" method, are also used.

As an alternative to welding, metal-to-metal cold curing adhesives can be used, although the setting time can be a disadvantage. A relatively cheap fastening method is the use of screws or rivets.

The raw edge of steel is often difficult to conceal, but in certain cases it can be done by edging with p.v.c. extruded sections.

Another difficulty is that many of the more expensive cubicles need an attractive appearance inside as well as outside. The usual method of stove enamelling is not suitable, but one possibility is to form a rigid frameless structure using a double skin with spacers where necessary.

Bearing in mind competition from stove-enamelled cubicles which have smooth, uniform exteriors, it seems wise not to attempt to disguise the non-uniformity at corners, but to emphasise them as a feature of design.

This is an extract from a paper by W. N. Jenkins, B.Sc., A.M.I.E.E., of the British Iron and Steel Research Association, given at the 1959 annual conference of the Institute of Sheet Metal Engineering.

HIGHLIGHTS AT THE DESIGN CONFERENCE

Here is a preview of the subjects to be dealt with at the Engineering Materials and Design Conference at Earls Court from February 22-26

Rotating Shaft Seals. *By E. T. Jagger.* Broad survey of the types available and important design principles. The factors that must influence their choice and the eventual design compromise (i.e., performance *v.* cost and space.)

Reinforced Plastics. *By A. W. Thompson.* Their new place in engineering, and the advantages of their unique characteristics. The use of plastics foam to stabilise thin reinforced plastics laminates is discussed in detail.

Preliminary Design of Rubber Components. *By A. N. Gent.* Discussion of recent applications (rail track fastenings and bridge mountings) as soft, compact springs. Elements of spring design, reasons for using rubber, and application techniques.

Weldable High-strength Stainless Steels. *By J. I. Morley.* Discussion of low-carbon martensitic chromium-nickel steels and of the semi-austenitic precipitation-hardening steels. An indication of their metallurgical characteristics, and ways of using them.

Role of Standards in Design. *By R. K. Whitehead.* Benefits of using national and company standards to both maker and customer. Basis for their formulation. Advantages of designing standards into a job. Simplification of production and stocks.

Magnesium Alloys for Engineering Use. *By P. A. Fisher.* Properties and characteristics of magnesium alloys. Some details of technology in their application are discussed and typical examples given. How their uses may develop in the future.

Beryllium as a Structural Metal. *By A. J. Martin.* Comparison between its properties and those of conventional engineering materials. Why it is used in supersonic missiles as a heat-sink; its future in structural applications, particularly in aircraft.

Vacuum Melted Materials. *By H. C. Child.* Titanium alloys. Martensitic steels. Austenitic alloys. Alloys for turbine rotor and stator blades in wrought and cast conditions. Ball-bearing materials. Ultra-high tensile steels.

High-pressure Hydraulic Equipment. *By D. E. Turnbull and H. Stephens.* Seals and their application and behaviour. Hydraulic servo-mechanisms. Hydrostatic transmission. Hydrostatic thrust bearings. High-pressure flexible hose. Survey of synthetic and non-inflammable fluids.

Investment Castings Produced by Centrifugal Methods. *By I. L. Gwynn.* Deals with their design and application. Influence of design factors such as component form, material properties, production methods. Properties of cast material. Future of the process.

Industrial Design in Engineering. *By R. M. Kay.* Discusses the factors that contribute to good design, i.e., management backing, training, correct analysis of initial design problem, time factor, etc.

Pumps for the Processing Industries. *By J. O. S. Macdonald.* Various pumps available are classified and examined for their suitability for specific uses. Rules for correct designing of suction pipework. Shaft sealing. Self-priming pumps. Selection of construction materials.

Cast Iron as an Engineering Material. *By H. Morrogh.* Review of the family of cast irons offering range of properties. Grey and white cast irons. Ductile cast irons in the form of nodular or S.G. irons, and as blackheart or whiteheart malleable irons. Special properties from cast-iron alloys.

Plastics for Use at High Temperatures. *By V. E. Yarsley.* Materials at present available. Forecast of future needs for air and space travel. Current work with (a) carbon compounds and (b) semi-inorganic and inorganic polymeric materials.

Photoelasticity. *By C. Snell.* Scope of this method of experimental stress analysis, and how it can help the designer. Its value in explaining the mechanism by which structures or components function or in proving a design.

Engineering Design in Britain, Germany and Russia. *By J. Shapiro.* Design and the status of the designer in Britain are discussed in relation to trends and attitudes in Germany and the Soviet Union. Some broad general conclusions are offered.

Engineering Design for Safety. *By B. Shackel.* Present onus of liability is on user's employer and very little on designer, who might more often prevent accidents at source. Research surveys. Principles and practice of safe design.

The Case for Industrial Design. *By H. A. Nieboer.* The industrial designer must develop engineering machines and other products that will embody and expand human capacities, and which will avoid domination of the user or consumer.

Background information on principal speakers at the conference was published in our January issue.

For last-minute registrations for the conference, apply now to the Secretary, E.M. & D. Conference, Drury House, Russell Street, London, W.C.2.

THE BONDING OF THREADED JOINTS

This article describes the methods and results tests carried out by the Ministry of Aviation with a group of thread-bonding cements designed as an alternative to such devices as lock nuts

by R. W. BRYANT and W. A. DUKES *

IT is common experience that threaded joints can be loosened by vibration or mechanical shock even though initially they are tight. A theory of the mechanism of loosening caused either by vibration or by mere fluctuation of bolt tension, not necessarily rapid, has been developed and experimentally confirmed.[1, 2, 3]

Many devices, such as lock nuts, have been developed in order to prevent this loosening. An alternative approach, which is under investigation at the Ministry of Aviation materials research laboratories at Waltham Abbey, is to use a cement to bond the threads together.

The stresses in a cemented threaded joint may be conveniently visualised by considering the unrolled planar model shown in Fig. 1. The inclined plane represents the bolt thread, and the angle of inclination α is the lead angle of the thread (usually between 1 deg. and 4 deg.). P is the pitch and D_E the effective diameter of the thread, both in inches (see Fig. 2).

The failing torque M ft.lb. (= 12M in.lb.) of the cemented joint is represented by a horizontal load $\frac{12M}{D_E/2} = \frac{24M}{D_E}$ lb, applied to the block in Fig. 1 which represents the nut. This load may be resolved into two components, one normal and the other parallel to the inclined plane of the thread:

$$\text{i.e., } \frac{24M \sin \alpha}{D_E} \text{ and } \frac{24M \cos \alpha}{D_E} \text{ respectively.}$$

The normal load will not, in this simple treatment, result in any shear stress on the cement lying between the block and inclined plane (that is, the nut and bolt). The load parallel to this plane, however, causes a shear stress on the cement. In the absence of stress concentrations, this stress is equal to the load divided by the area A of the surface between nut and bolt. The maximum stress is equal to the shear strength S of the bond or of the cement, whichever is the less, and corresponds to the failing torque M:

$$S = \frac{24M}{D_E A} \cos \alpha \qquad (1)$$

As 1 deg. $< \alpha <$ 4 deg., $1{\cdot}000 > \cos \alpha > 0{\cdot}998$; that is, $\cos \alpha$ may be taken as unity.

The area of contact A is equal to the length of the axial cross-section through the surface of one triangular thread, as shown (thickly drawn) in Fig. 2, multiplied by the peripheral length of one turn (πD_E), multiplied by the number of turns (L/P, where L is the length of engagement). In the Whitworth system this cross-sectional length is equal to 1·71P, and in the Unified system to 1·83P.

$$A_W = 1{\cdot}71\pi LD_E \qquad (2a)$$

and

$$A_U = 1{\cdot}83\pi LD_E \qquad (2b)$$

and thus for triangular threads in general

$$A = 1{\cdot}77\pi LD_E \text{ very nearly.} \qquad (2c)$$

Substituting in Equation (1),

$$S = \frac{24M}{1{\cdot}77\pi LD_E^2} = \frac{4{\cdot}3M}{L.\,D_E^2} \qquad (3a)$$

or

$$M = \frac{S}{4}.\,L.\,D_E^2 \text{ nearly.} \qquad (3b)$$

Experiments in Joint Strength

Recently, a range of novel thread-bonding cements has become available in this country. Known as Loctite, they are manufactured by American Sealants Co., and marketed in this country by Douglas Kane Ltd. Descriptive articles have been published.[4, 5] The five grades available are said to have the following shear strengths: A and D, 750-1,000 p.s.i.; C, 300-400 p.s.i.; E, 150-200 p.s.i.; H, 75-100 p.s.i.. The present investigation has been limited to grades D, C and E. The strengths (that is, the failing torques) of steel threaded joints of various dimensions, and the shear strengths of planar steel joints, have been measured.

TESTING METHODS—All the threaded joints were made between steel studs or bolts of ¼-in. nominal diameter with threads conforming to the British Standard Fine system (16 t.p.i., B.S. 84 : 1940), and corresponding steel nuts of various thicknesses, all of medium fit unless otherwise stated. Components were cleaned, washed in trichloroethylene and dried with a clean linen cloth before use.

Sufficient cement was applied to both male and female

* *Ministry of Aviation materials research laboratories, Waltham Abbey.*

threads before assembly, usually with a brush, for excess material (subsequently removed) to be extruded from both ends of the joint during assembly. This technique ensured reproducible joints. Usually eight replicates were prepared and tested.

Cemented assemblies were tested after storage either (a) for one week at 25 deg. C. or (b) for one day at 25 deg. C. followed by one week at 75 deg. C. These storage conditions were chosen because they had been used before, although the manufacturers state that the ultimate strength is nearly reached after one day at room temperature.

Failing torques were measured either with a calibrated torque wrench or with a spring balance at a measured distance along a spanner or tommy-bar. The head of the bolt (or the stud) was held in a vice, and the torque applied to the nut in gradual increments (each not more than 10 per cent of the failing torque), usually with a ring spanner. The failing torque was taken as the lowest torque to cause continuous relative movement of the components.

ADHESION MEASUREMENTS—The cements were also tested in a standard adhesion test. The cylindrical test-pieces were of steel, with a cross-sectional area of 1 sq. in. (1·128 in. diameter). The plane ends of the test-pieces were abraded with fine (00) emery paper backed by a sheet of plate glass, and washed in toluene and dried before being coated with the adhesive. Two such pieces were then placed face-to-face co-axially, compressed in a jig at 100 p.s.i. pressure and stored for a week at 75 deg. C.

After cooling to room temperature and removal from the jig, each pair of test-pieces was fitted symmetrically in a shear-test jig, shown in Fig. 3, so that the joint was in the central slot. The extension rods were gripped in a standard testing machine and pulled apart at the rate of 0·2 in./min. The failing load (i.e., the shear strength) of the joint was recorded.

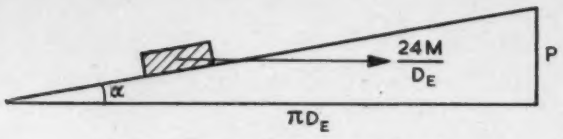


Fig. 1. Planar model of a screw thread

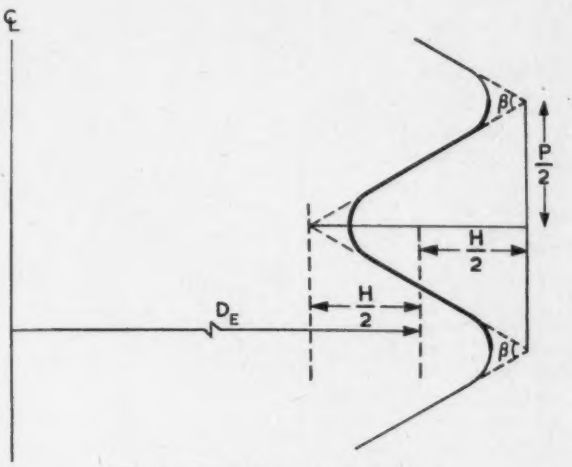


Fig. 2. Cross-section of screw thread.

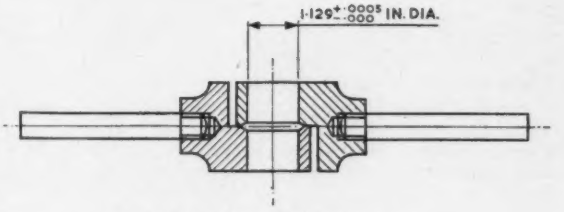


Fig. 3. Jig for adhesive shear test.

Results Obtained

The effect on the joint strength (that is the failing torque) of each of the variants considered will be discussed in turn. The detailed failing-torque determinations are not reproduced, for the sake of brevity. A variation of ± 30 per cent in the strength of replicates was usual.

EFFECT OF PERIOD AND TEMPERATURE OF STORAGE BEFORE TRIAL—Only one set of medium-fit nuts and bolts cemented with each grade was tested after both the storage conditions. The mean values for each grade (plotted in Fig. 4) are not greatly different, and the ranges (shown in Table 2) overlap considerably. The mean of the results for the unheated specimens cemented with Grade E was higher than that of those which had been stored at 75 deg. C.: the opposite was the case with the other two grades of cement.

There is thus no significant difference between the strengths of cemented joints after storage either at 25 deg. C. or at 75 deg. C. for one week.

EFFECT OF THE LENGTH OF ENGAGEMENT—The means of all the results with medium-fit joints are shown in Fig. 4, where the failing torque M is plotted against the length of engagement L (both on a logarithmic scale). Results for joints stored at both temperatures are included. The regression lines (log M upon log L) of all determinations are shown for each grade of cement. The slope l of each line may be termed the length of engagement index in the following equation:

$$\log M = l \cdot \log L + \log M_{L=1}$$

or

$$M = M_{L=1} L^{l} \qquad (4)$$

The values of the parameters for each grade of cement are shown in Table 1.

When the scatter of individual determinations is taken into account, it will be seen that for practical purposes the failing torque is proportional to the length of engagement. With Grade C ($l = 0{\cdot}75$), a fourfold increase in L results in a failing torque 2·83 times greater, as compared with 4·72

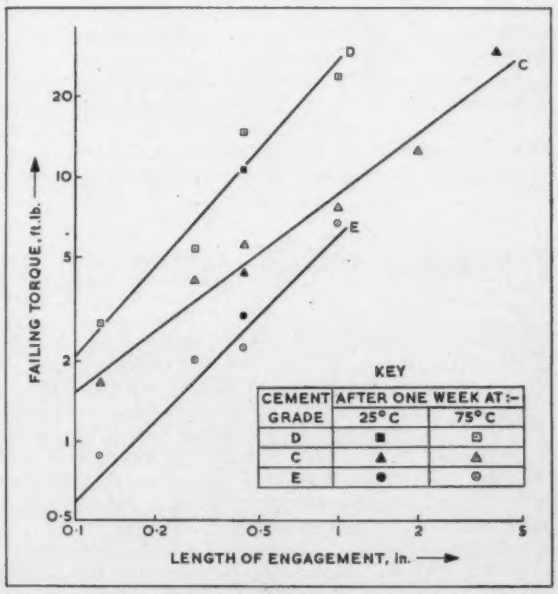


Fig. 4. Failing torque of ½ in. B.S.F. threaded joints of various lengths of engagement.

TABLE 1. Parameter values for grades of cement

Grade	ML=1 (ft. lb.)	
D	27·4	1·12
C	8·6	0·75
E	6·1	1·02

times greater with Grade D ($l = 1{\cdot}12$). This difference is about the same as the observed variation among replicates.

The proportionality of failing torque with the length of engagement for any given circumference, as predicted in Equations 3, is thus confirmed.

EFFECT OF CLOSENESS OF FIT—Components with nuts 0·44 in. thick were available of close, medium and free fit as specified in B.S. 84: 1940. The tolerance for close fit is two-thirds, and for free fit one-and-a-half times that for medium fit. The failing torques of these components, with each grade of cement, are summarised in Table 2.

For each cement, except possibly for Grade D, the mean values for each degree of fit are not greatly different, and the ranges overlap considerably. Although there is a slight indication that closer-fitting joints may be somewhat stronger, this is negligible when compared with the scatter. For practical purposes, the failing torque of a joint is independent of the degree of fit.

EFFECT OF DIAMETER—The effect of the diameter on the strength of joints has not been assessed in the present work. However, with many other cements the failing torque has been found to be proportional to the square of the effective diameter, as predicted in Equations 3.

STRENGTH OF EACH GRADE OF CEMENT—As has already been shown, in the absence of stress concentrations the shear strength of the cement (or of the substrate/cement bond—whichever is the less) may be calculated from the failing torque of cemented threaded joints of known dimensions. This has been done for the three grades of cement, taking the least-square mean failing torque for L = 1, as given in Table 1, and knowing that for ½-in. B.S.F. threads D_E equals 0·46 in. The results are shown in column (d) of Table 3.

For comparison, the shear strengths of planar bonds between right cylinders of steel have been measured, using the standard method given above. The adhesive film was about two thousandths of an inch thick. Means of the results are shown in column (c) of Table 3. All failures appeared to be adhesive rather than cohesive.

The shear strengths quoted by the manufacturers, which are shown in column (b), are only of general interest as the method of measurement is not known.

The planar adhesive test yielded a strength rather more than five times that found in the threaded joints. This ratio,

TABLE 2. Failing torques of ½ in. B.S.F. threaded joints of various degrees of fit

Grade of Cement	Fit	Failing Torque (ft./lb.)		
		min.	mean	max.
D	Free	10·0	13·5	19·0
	Medium	8·00	14·6	21·0
	Medium*	8·00	10·6	15·0
	Close	19·0	23·4	27·0
C	Free	3·00	4·44	6·50
	Medium	3·50	5·56	8·00
	Medium*	3·63	4·38	5·50
	Close	4·50	5·19	6·50
E	Free	0·88	1·97	3·63
	Medium	1·13	2·26	3·63
	Medium*	2·00	2·97	4·13
	Close	2·00	2·97	4·13

All after 1 day at 25° C. followed by 1 week at 75° C., except those distinguished by an *, which are after 1 week at 25°C.

TABLE 3. Shear strength of bonds

Grade of Cement	Shear Strength (p.s.i.)			Ratio n $\left(=\frac{\text{col. (c)}}{\text{col. (d)}}\right)$
	Claimed by manufacturers	In planar steel/steel bond	In steel threaded joints (see Eqn. 3a)	
(a)	(b)	(c)	(d)	(e)
D	750–1,000	2,993	563	5·3
C	300–400	967	177	5·5
E	150–200	836	125	6·7

n, shown in the last column of Table 3, is relevant to the incidence of stress concentrations.

The failing torque (in ft. lb.) of steel threaded joints of any dimensions may be predicted by substituting in Equation (3a) the experimental values of the shear strength shown in column (d) of Table 3. The following approximations suffice:

for grade D, $M = 130L \cdot D_E^3$,
for grade C, $M = 40L \cdot D_E^3$,
for grade E, $M = 30L \cdot D_E^3$.

A variation of ± 30 per cent is usual in the strength of replicates, even when the joint is completely filled with cement. A lower strength is to be expected if the joint is starved.

REFERENCES
1. J. N. Goodier and R. J. Sweeney, *Mech. Engng*, N.Y., 1945, **67**, 798.
2. R. J. Sweeney, *Machine Design*, 1946, **8**, (6), 139.
3. J. A. Sauer *et al.*, *ibid.*, 1950, **22**, (8), 133.
4. *Materials and Methods*, 1956, **44**, (4), 98.
5. R. H. Krieble, *Machine Design*, 1957, **29**, (19), 129.

Crown copyright reserved. Reproduced with the permission of the Controller, H.M.S.O.

STRENGTH OF CERAMICS AT HIGH TEMPERATURES

CERAMIC materials are being investigated at the National Bureau of Standards for the Air Force to develop a better understanding of their strength at elevated temperatures. As part of this programme, the strength of aluminium oxide single crystals (sapphire and ruby) has recently been studied at temperatures between 600 and 1000 deg. C. The study supports the theory that, in properly oriented crystals, plastic deformation relieves stress concentrations, thus increasing crystal strength.

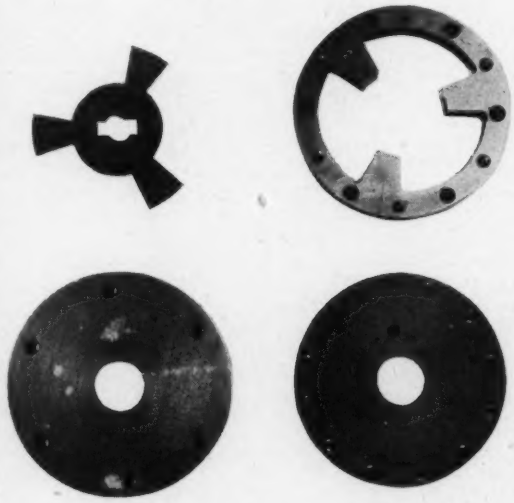
The widespread use of these ceramic materials makes it desirable to investigate the factors controlling their strength at elevated temperatures. However, a study of pure polycrystalline ceramics is complicated by grain boundaries and also by the interaction of the single crystal grains.

The strength of polycrystalline aluminium oxide is known to decrease with increasing temperature above 800 deg. C. However, in one set of measurements on single-crystal aluminium oxide, crystal strength increased with temperature in this range. It was suggested that this might be caused by very small amounts of plastic deformation, that is, failure may have begun at points where the local stress was much greater than the average applied stress. Plastic deformation might then have reduced the degree of stress concentration with the result that a larger average stress could be sustained before failure occurred.

designer's notebook

Pneumatic Servo Mechanism uses Vane Motor

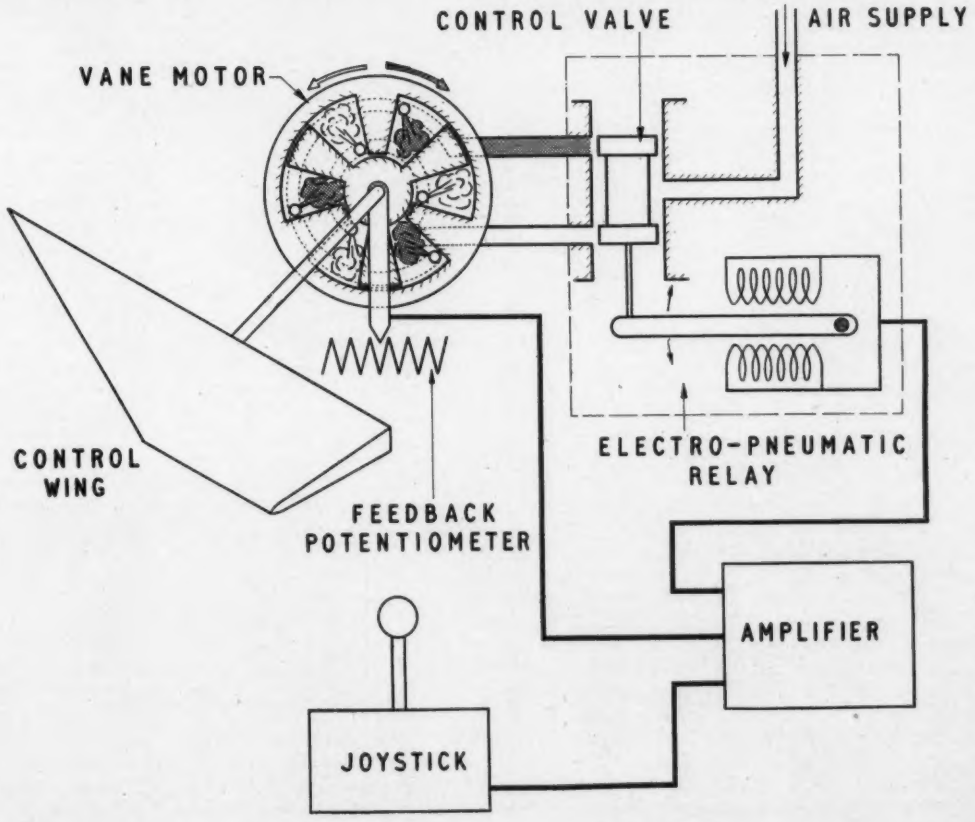
THE accompanying diagram illustrates the working principle of an ingenious servo mechanism displayed at the recent open day at the Armament Research & Development Establishment, Fort Halstead. Developed as a compact means of moving the control surfaces on a missile, the mechanism was impressively demonstrated by a working model. A bench mounted joystick, movement of which controlled corresponding movement of a dummy missile control surface, enabled the visitor to appreciate the very high response rate achieved. The movement of input and output traces on a two-channel oscillograph appeared to be simultaneous. The response rate for which the model was developed was around 20 c/s.



An electrically-controlled valve, the dumb bell shaped plunger of which is maintained in balance by the incoming air stream, controls the supply of air to the vane motor which is also in a balanced state when not being operated. To this valve is fed an error signal which is the difference between the input voltage and the output of a potentiometer on the output shaft. Power for operating the relay is obtained from a transistor amplifier which is designed around the parameters of the other components to give the required performance.

The photograph illustrates the components of the vane motor which is capable, in the form shown, of an angular movement of about 30 deg. Partly annular grooves in one of the side plates connect the inner and outer ports to each side of the air valve.

The simple construction of the motor, taken in conjunction with the high rate of response which can be achieved with it, appear to offer exceptional possibilities of development for commercial applications.



PROBLEMS IN DESIGN

Problem: to provide a means whereby a rotating shaft can be made to reciprocate axially a second shaft, coaxial with the first, one revolution of the input shaft causing one complete reciprocation, without the use of cams, springs or gears.

THIS problem which we set in our December issue gave stimulus to the ingenuity of a very large number of readers, and the best of the entries are shown here. In some cases similar solutions were submitted by more than one reader, but we are sorry it is not possible to publish all versions and variations. The solutions were, in general, of a much higher standard than those sent in for the previous problem—and we feel inclined to withdraw some remarks we made in December about the lack of appreciation of space linkages!

A large number of valid solutions is possible to the problem posed, when stated as baldly as above, without further particulars of input speed of rotation, power to be transmitted, acceleration data or physical limitation as to the size of the mechanism. The solutions received are therefore divided into several categories, as follows:

(i) Perhaps the commonest of the first type of entry is that of J. Munford (Fig. 1). It is suitable for light loads and low speeds only and the geometry is only suitable for small movement of the output shaft. Ball joints used in this way to take reciprocating loads axially, as well as main rotational loads, can be only lightly loaded. Restraint against torque for the linkage must, in this type, be on the output side, an obviously poor feature, and a long bearing is necessary if the load on the output shaft is offset from the axis. A better version, for heavier duty, is that coming from H. R. Holliday (Fig. 2). We consider, however, that a key-way is a poor method of providing torque restraint, and that a milled slide and flatted shaft or a splined shaft are better methods. A still better solution in this category is that of A. D. Stiles (Fig. 3). Here we have the basis for a rugged mechanism for heavy duty. Double thrust bearings, Hooke's joints and a linkage which transmits thrust axially are all excellent features, and there is no need for a key-way or splined output shaft.

(ii) In the second category are to be found mechanisms of the swash plate type and it may well be objected that

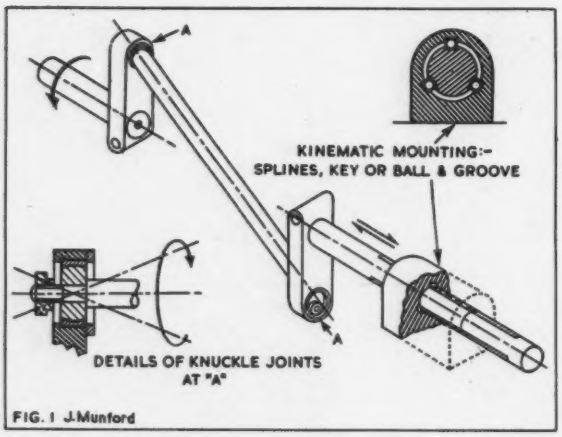


FIG. 1 J.Munford

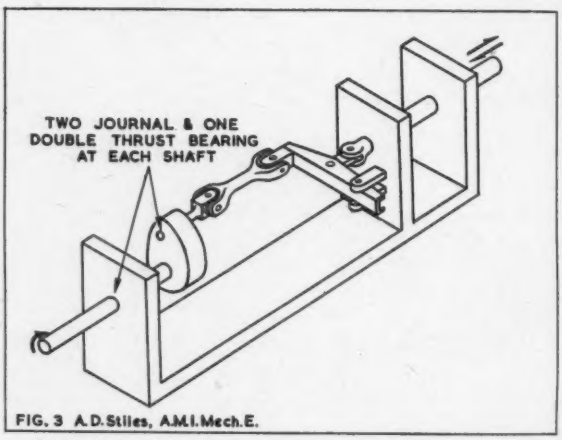


FIG. 3 A.D.Stiles, A.M.I.Mech.E.

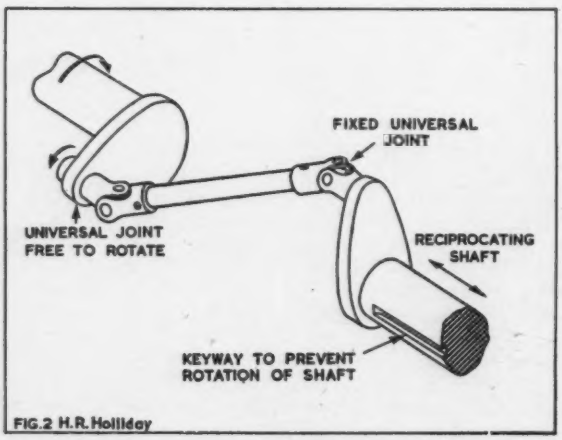


FIG.2 H.R.Holliday

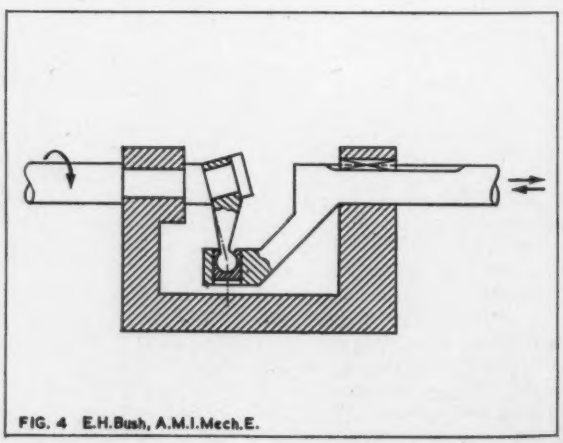


FIG. 4 E.H.Bush, A.M.I.Mech.E.

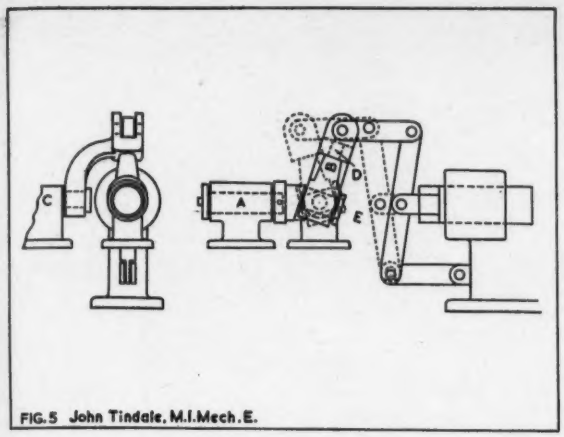


FIG. 5 John Tindale, M.I.Mech.E.

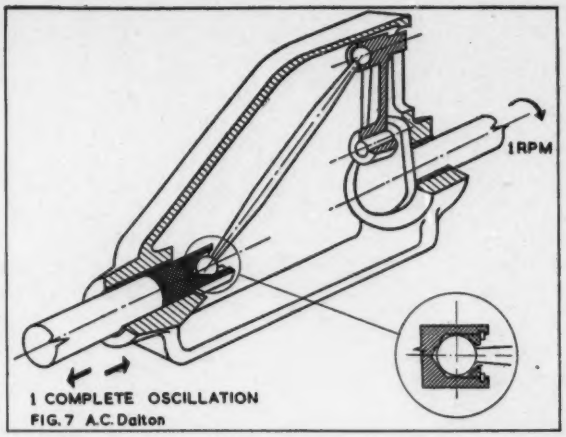


FIG. 7 A.C. Dalton

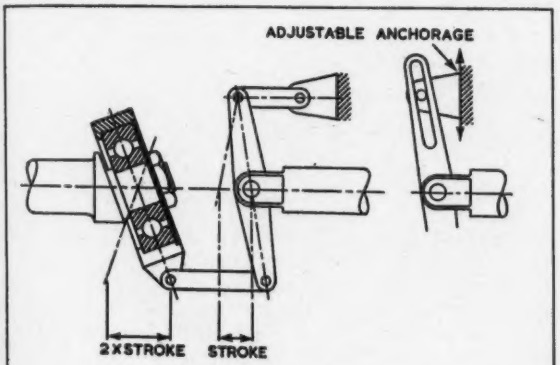


FIG. 6 W.P. White

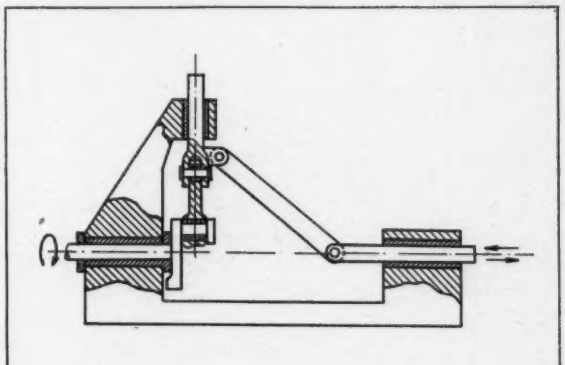


FIG. 8 J.A. Barnes

these are, in fact, in the cam category. We have decided that, as the matter is debatable, they should be included. Fig. 4, from E. H. Bush, would be suitable for light duty only. The best solution of this type was that of J. Tindale (Fig. 5) for the following reasons: torque restraint occurs on the input side and, unlike in Fig. 4, there are no sliding pairs in the linkage, as the centre lines of the bearing axes of A, B, C, D and E meet at a point on the shaft axis—a cunning feature. Perhaps the ideal solution in this category would be the incorporation of the ball-bearing feature of W. P. White's solution (Fig. 6) with the linkage of J. Tindale. Unfortunately, Mr. White's otherwise excellent solution contains an error, in that the lug on the bearing housing must be free to pivot and not rigid as shown. He has overlooked the swash effect.

(iii) Entries in this group used a crank or eccentric on the input shaft, but varied in the method of turning the movement through 90 deg. A. C. Dalton (Fig. 7) employs a sliding torque constraint on the input side (a good feature), but then uses a ball-ended rod to the axis of the output shaft to effect reciprocation. This is good in that loads are axial, but the use of a ball-ended rod would be suitable for small loads only. For such duties the fork end linkage from J. A. Barnes (Fig. 8) would be suitable.

Many entrants in this category used a bell crank, the best of which we consider to be that from T. Sherwen, M.I.Mech.E., M.S.A.E., M.I.B.A.E. (Fig. 9) in that sliding pairs are avoided except on the output shaft. Another typical version using an eccentric and having two sliding pairs, one of which could have been avoided on the output side, came from G. J. Hawes (Fig. 10).

(iv) In the fourth and last category we group the unusual, the unexpected and the bizarre. From L. F. V. Russell came Fig. 11 which is an ingenious and interesting solution, but suitable only for lightly loaded conditions. It relies on the angle at which the axis of a friction wheel, driven by the input shaft, lies to the axis of the input shaft. The friction wheel pivots in a frame which carries the output shaft and the pivoting action brings about a reversal of movement. Reversal is effected by a lever and snap-action toggle mechanism, the lever being operated by adjustable stop screws. An interesting feature of this motion is that not only can the amplitude of the output reciprocation be varied, but stop screws on the snap-action toggle mechanism itself can be set in such a way that the angle of the friction wheel to the input shaft can be varied in several ways. The helical path the friction wheel traces on the input shaft can be variable and output can be in phase or out of phase with rotation. This is not a requirement of the problem as set, but is nevertheless interesting.

We did not specifically rule out hydraulic solutions, and we include therefore that of A. Parker (Fig. 12), which caters for situations where the two shafts are in line, but too far apart to be connected by mechanical means.

Nor did we anticipate the odd solution submitted by A. M. Wooster (Fig. 13) in which a magnet attached to the input shaft rotates as the rotor of a simple generator whose field coil is connected to a solenoid and alternates reversals of magnetic flux, causing the reciprocation of a bar magnet to which the output shaft is fixed. At just what speed rotation of the input shaft would satisfactorily reciprocate the output shaft in phase remains a mystery to us.

A common fault of a number of otherwise ingenious entries was the presence of sliding shafts also subjected

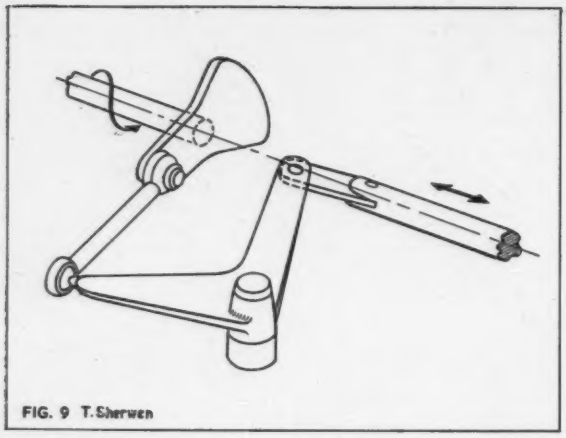


FIG. 9 T. Sherwen

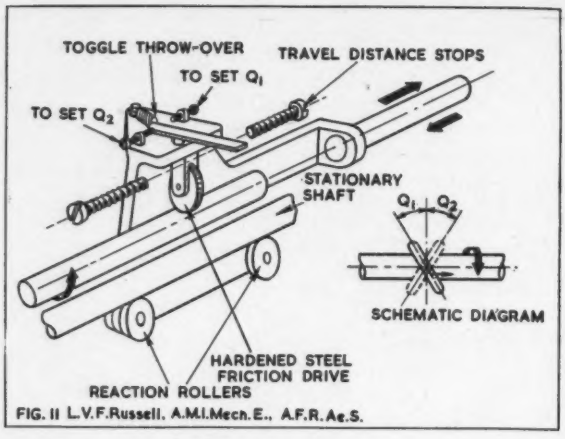


FIG. 11 L.V.F.Russell, A.M.I.Mech.E., A.F.R.Ae.S.

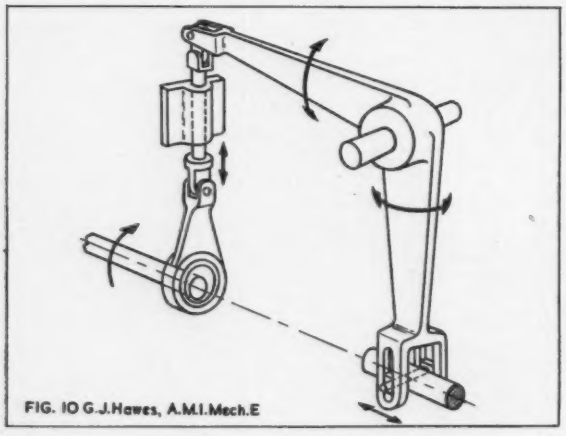


FIG. 10 G.J.Hawes, A.M.I.Mech.E

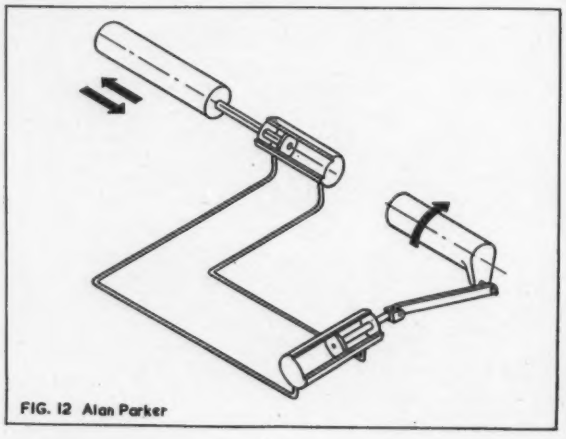


FIG. 12 Alan Parker

to bending. In very few cases did it appear that any thought had been given to the mechanism shown being lubricated. While we did not expect to see large wick oilers and lubrication points obviously displayed, some mechanisms were clearly not practicable as hardware propositions for this reason. Another common error was that in few cases had the mechanism been considered in a heavily loaded or stalled condition, i.e. when the mass being reciprocated is heavy one and twisting components in the linkage occur, unless this is taken out at the input side. In future problems we shall be more specific in defining the design requirements and possibly thereby eliminate some of the wilder entries.

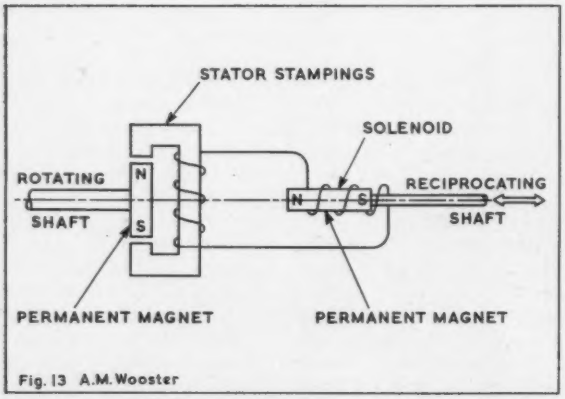
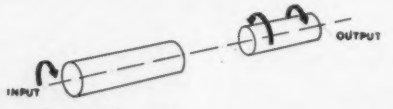


Fig. 13 A.M.Wooster

Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12 X 12 in., please !), to The Editor, E. M. & D., marked "Problems in Design (February)". Closing date March 15.



THIS MONTH'S PROBLEM (set by W. P. White)

To provide a means whereby a rotating input shaft can be made to reciprocate angularly an output shaft on the same axis.

Data: Input rotates at constant speed, output to reciprocate angularly one complete revolution clockwise and then one complete revolution anti-clockwise. Neither shaft is to move axially. Two revolutions of input shaft causing one complete reciprocation of output shaft, preferably without cams and friction drives.

Shaft size: 1 in. dia. Input shaft speed: 100 r.p.m.

Torque transmitted: 20 lb. ft.

The mechanism to be contained within a radius of 6 in. about centreline.

We welcome design problems from our readers. These should be in the fields of simple mechanical, hydraulic or compressed air engineering and not specific to a particular application. All problems published will be paid for.

HOW TO SELECT LUBRICATING GREASES

Alongside the innumerable petroleum greases available to the designer, there are now many synthetics from which to choose for certain mechanisms. Here is a survey embracing both types, showing how they should be used

by MOLLY NEAL, B.Sc., D.I.C., A.F.R.Ae.S.

DURING recent years the scope of lubricating greases has widened enormously. They are used (to quote one lubricant manufacturer) "for a diversity of purposes ranging from the eccentrics of a walking dragline doing a few revolutions per day to the reduction gears of electric tools doing 20,000 r.p.m.". There are greases applied in fractions of an ounce to sealed-for-life ball-bearings, and there is grease applied by the ton to the slipways of a launching cradle. There are greases resistant to being washed away by water, and others by petrol or resistant to specified acids, greases remaining soft at sub-zero temperatures and others which are happy at 400 deg. F or above.

Grease is defined in the A.S.T.M. *Petroleum Testing Manual* as "a solid to semi-solid product of dispersion of a thickening agent in a liquid lubricant. Other ingredients imparting special properties may be included". In comparison with oils, greases have the ability to form a seal preventing the entry of dirt and moisture into working parts; on the other hand, they cannot function as coolants. Generally speaking, therefore, apart from ball and roller bearings, the use of greases is likely to be restricted to fairly low-speed applications. In the case of ball and roller bearings, grease lubrication is being increasingly used even for high-speed applications, since its sealing properties simplify the problem of housing design; the grease must, however, be carefully selected for any given design of bearing and the only way known at present to ensure satisfactory results is by extensive performance tests.

Traditional greases comprise a metallic soap—formed by the reaction of a fatty oil with an alkali—and a petroleum oil finely dispersed in the matrix of the soap. By far the majority of greases in use today are of this type, but within the last few years, primarily in response to the demands of the aircraft and guided missile industries for extreme temperature lubricants, synthetic greases have been introduced in which the mineral oil component is replaced by synthetic oils; and "non-soap" greases using finely divided materials such as silica, specially treated clays, or dyestuffs as the thickening agent in place of metallic soaps. These are special purpose developments and are, naturally, more costly.

Metallic Soap Greases

These cover the majority of ordinary applications and are often classified according to their metallic base, i.e., calcium or lime soap greases, sodium soap greases, lithium soap greases in recent years and, less frequently encountered, aluminium soap greases. While this classification gives some guide to the possibilities of the grease, certain manufacturers emphasise that the suitability of a grease for any particular application depends not so much on the type of grease as on the characteristics of a particular grease and the service conditions—the type of loading, speed, temperature, how the grease is applied and the environment. It is, nevertheless, useful to look at the broad properties of the different metallic bases. Table 1 gives a picture of the general characteristics of greases. For many purposes the various greases may be blended to achieve a combination of properties.

One of the properties commonly quoted in grease specifications is the "drop point"—the temperature at which the grease melts sufficiently to form liquid drops. If a conventional lime soap grease is heated above its drop point, its constituents may separate and not reform into a grease-like structure on cooling. Aluminium-based greases, although they do not separate when heated, can change their texture on cooling below the drop point. Such greases, therefore, are restricted to operation at temperatures below their drop point. Conventional lime soap greases are restricted to temperatures below 140 deg. F. because above this temperature their water content begins to evaporate. Certain other calcium-based products, less frequently used, are not subject to this limitation; neither are certain of the soda and all lithium soaps. Soda- and lithium-based greases, moreover, have higher drop points than ordinary lime-based greases. However, for continuous operation, working temperatures considerably below the drop point are recommended because the oxidation rate of the petroleum component increases rapidly with rising temperature and the lubricating properties diminish correspondingly. Just how high the working temperature can be depends not only on the characteristics of the grease but also on how it is fed to the working part—whether it has to withstand an apparatus lifetime of use, or whether it is frequently changed.

Although lime-based greases are restricted to lower temperatures than soda-based greases, they have the advantage over the latter when called on to operate under conditions

of water washing, because soda-based greases emulsify in the presence of water. The lithium-based greases are both water resistant and can withstand higher operating temperatures. It is not uncommon nowadays for calcium- and lithium-based greases to contain a rust-inhibiting additive to ensure the prevention of corrosion in underwater operating conditions.

Different applications require greases of different stiffness and texture. The stiffness, or consistency, of a grease may be expressed in manufacturers' specifications either in terms of "N.L.G.I." number (National Lubricating Grease Institute) or in A.S.T.M. or I.P. penetration consistency, i.e., the depth (measured in tenths of a millimetre) that a standard cone penetrates into a grease sample in 5 sec. Usually "worked" consistencies are quoted; that is, the consistency is taken after the sample has been worked for 50 double strokes in a standard grease worker. The relation between N.G.L.I. classification and A.S.T.M. or I.P. penetration consistency is as follows:

N.L.G.I. Class.		*Worked Penetration*
0	very soft	355/385
1		310/340
2		265/295
3		220/250
4		175/205
5		130/160
6	very stiff	85/115

The worked penetration still does not necessarily indicate the behaviour of greases in service. Some greases tend to soften excessively when worked at high rates or for long periods, and this could lead to leakage of the lubricant. The property of resisting softening on working is known as mechanical stability, and is an important consideration in the selection of greases for ball and roller bearings.

While, roughly speaking, the softer greases serve for light duties and stiffer grades would be employed at heavier loadings, in fact the stiffest greases are of limited application, among which is the lubrication of water-pump glands. Increasingly, the tendency is to use greases of soft to medium consistency incorporating higher viscosity petroleum oils, and for really severe loadings extreme pressure additives.

Where the grease has to form its own seal as well as acting as lubricant—as, for instance, in spring shackles, open gearboxes, and wire ropes—a stringy tenacious grease would be selected. Soft buttery greases are required for centralised lubrication systems where the grease is fed through long fine-bore pipelines. General purpose "cup" greases—fed by means of screw-down pressure cups—of medium soft consistency are often favoured for plain bearings running at normal temperatures. Spring-loaded pressure cups are not recommended since they tend to cause separation of greases other than those with an aluminium base.

Greases suitable for the lubrication of grease-packed ball and roller bearings are usually specified by the bearing maker on the basis of rigorous performance tests. Generally for moderate speeds, the majority of such greases will be of medium soft consistency—softer greases may "slump" too easily and, circulating too freely, be softened still more by the churning action of the rolling elements, while stiffer greases may not adequately feed the sliding surfaces. It is important that bearing housings are not overfilled and sufficient space is left for grease expelled from the bearing, otherwise high running temperatures will ensue. High mechanical stability is necessary to resist changes of consistency under churning by the balls or rollers and their cages; and high resistance to oxidation is required if a sealed bearing is to have an adequate life. Rust protection, too, is a desirable quality. Some grease manufacturers quote a "speed factor" or "N.D." value for their greases, that is, an indication of the peripheral speed, in terms of r.p.m. times diameter in millimetres, which

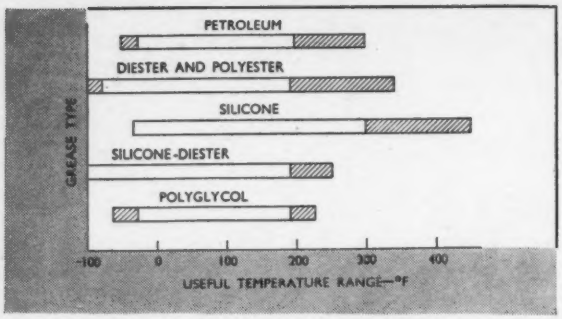


Fig. 1. Temperature range for ball-bearing greases. Shaded areas covered only with special products or by relubrication.

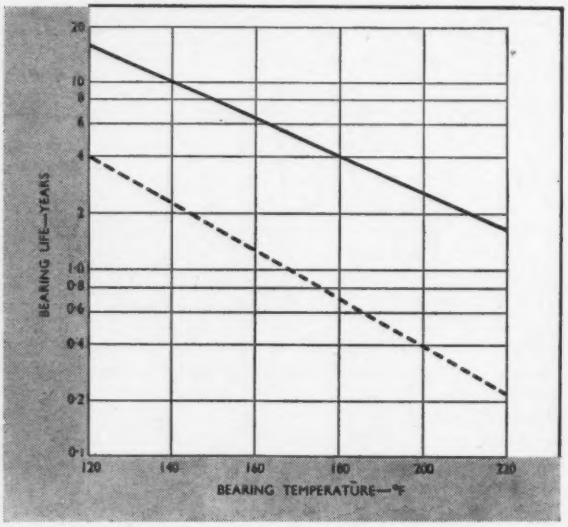


Fig. 2. Variation in grease life with temperature. (For 306 size ball-bearings at 3,600 r.p.m., 160 lb. radial load).
———— best present petroleum greases.
— — — — — best ten years ago.

the grease will withstand. The general purpose anti-friction lubricants are good for N.D. values ranging from 100,000-300,000; but recently special purpose greases have been developed with speed factors as high as 500,000-600,000.

Within the range of general purpose petroleum greases will be found some capable of working at temperatures up to 350 deg. F., although around 200 deg. F. is a more usual figure for continuous service (Fig. 1). At higher temperatures petroleum oils deteriorate rapidly. Solid additives with good lubricating properties, such as quasi-colloidal graphite or micronised molybdenum disulphide, are often included in greases intended for high temperature operation; in use, it is claimed that these solids are absorbed by the metal bearing surfaces, filling in the "valleys" and increasing the effective bearing area and thereby reducing the friction coefficient. Moreover, should the carrier grease be dissipated by excessive heat, the solid lubricant remains as a dry film preventing seizure. Molybdenum disulphide will withstand temperatures up to 800 deg. F. without deterioration of its lubricating properties, and colloidal graphite remains effective to still higher temperatures. Under extreme pressure conditions, molybdenum disulphide is particularly effective, the film being capable of withstanding pressures up to 400,000 p.s.i.; but to achieve good results—particularly

TABLE I. General characteristics of greases

Soap Base	Texture	Dropping Pt. (Approx.) °F.	Condition after Heating above Melting Pt. and Cooling	Max. Continuous Usable Temp. °F.	Effect of Water	Resistance to Softening Upon Working	Primary Use	Remarks
Calcium—general	Buttery	200–225	Separates	140	Resistant	Fair to poor	General purpose, for plain bearing and line shafting.	Max. service temp. limited due to destabilisation caused by loss of water. Have inherent rust-proofing properties.
High melting point calcium	Buttery	500 plus	Separates: when properly chemically stabilised, has non-separating properties	300	Resistant	Excellent	Ball, roller and plain bearings in automotive use including wheel bearings and chassis; industrial plants.	Used at temp. above those suitable for sodium-based grease. May return to homogeneous state upon cooling after being melted.
Calcium—resinate	Buttery	275	Foams at 200° F. Separates on prolonged heating	200	Resistant	Fair to poor	Rough heavy bearings operating at slow speeds; also skids, track curves and wagon wheels.	Usually used where low cost is a major factor
Sodium—general	Fibrous or smooth	300–450	No change if worked	250–300	Susceptible	Excellent to poor (varies greatly with composition)	Ball and roller bearings operating at low to medium speeds, and light to heavy loads; also on wheel bearings and chassis of automobiles and trucks.	Susceptibility to water can be improved by certain choices in composition. Provides rust protection in moist environments. Short fibred or smooth textured greases used on anti-friction bearings, while long fibred greases recommended for chassis lubrication.
Sodium—brick type	Hard-brittle	300–450	No change	300–450	Susceptible	Fair to poor (varies greatly with composition)	Driving journals of locomotives and similar bearings.	Usually applied directly against revolving journal.
Aluminium	Normally buttery. Tackiness polymer sometimes added	200	Changes texture upon cooling, but does not separate above melting point or below	200 (see remarks)	Resistant	Fair to poor	Where resistance to centrifugal force is desired.	Change texture on heating and on cooling: not recommended above 150° F.
Lithium	Buttery to stringy	360	No change if worked	250–300	Resistant	Excellent to poor (varies greatly with composition)	Aircraft lubrication at temperatures from −100 to + 300°F. and in automotive and industrial use.	Combination of water resistance with high dropping point is advantageous for many applications over a wide range of temperatures.
Mixed base sodium-calcium	Fairly buttery to fibrous	315	No change if worked	250	Susceptible	Excellent to poor (varies greatly with composition)	All types ball and roller bearings, and special applications at both high and low temperatures depending upon composition.	Combination of two or more soaps. Sodium-calcium is commonest example. Properties determined by major soap component.
Solid thickened greases	Smooth buttery to slightly stringy	500 plus	May harden after heating, but retains grease texture	Depends on oil component	Resistant	Excellent to poor	High temperature applications.	Solid thickeners may be finely divided activated clay, silica or carbon black.

Data by courtesy Regent Oil Co.

in high-speed ball-bearings—it is important that pure material of the correct particle size, suspended in a suitable carrier, should be used, and that it should be applied in the proper manner. Graphite and molybdenum disulphide also have important applications as "assembly compounds"; applied in the form of a high-concentrate paste during the manufacture of working parts, they form excellent running-in compounds.

Synthetic Greases

Recently greases thickened by non-soap gelling agents, such as the non-melting bentone greases, have been coming into use for operation at temperatures up to 500 deg. F. Some of these are not suitable for ball and roller bearing lubrication, being too stiff and thick.

For very wide ranges of operating temperature, extending as high as 700 deg. F., greases based on silicone synthetic oils appear at present to be the most promising. They are oxidation resistant, non-corrosive and water repellent, do not affect natural or synthetic rubbers, and their viscosity change with temperature is relatively small compared with petroleum oils. Unfortunately their lubricating and load-carrying properties are not so good; but here again the addition of finely divided molybdenum disulphide may be of great benefit.

At the low temperature end of the scale, the principal lubricants again are synthetics—the diesters and silicone diester mixtures, effective down to the temperatures of − 75 deg. F. and − 100 deg. F. respectively. Some of these greases have a relatively narrow temperature range, and to improve their lubricating properties at higher temperatures they can be supplemented with graphite or molybdenum disulphide either as dry films applied before assembly or as finely-dispersed additives.

One other class of special purpose greases must be mentioned—the radiation-resistant greases for nuclear power application. In conventional soap-thickened greases, nuclear radiation causes the soap structure to liquefy and the lubricating oil component to harden to a brittle solid. Certain types of petroleum hydrocarbons have, however, proved to be stable under radiation, and in conjunction with non-soap inorganic-base thickeners, satisfactory greases for atomic energy plant are now in service.

Figs. 1 and 2 first appeared in a paper, *Recent Advances in Grease Lubrication of Ball Bearings*, by E. R. Booser, given at the I.Mech.E. 1957 conference on lubrication and wear.

—Details of the main sources of supply of lubricating greases in the U.K. are given overleaf

MAIN U.K. SUPPLIERS OF LUBRICATING GREASES

LIME SOAP GREASES

Alexander Duckham & Co. Ltd.
Cup greases: three consistencies from medium to extra stiff, for plain bearings; operating temperature up to 100 deg. F. Gun grease: very soft for lightly loaded bearings; operating temperature sub-zero to 80 deg. F. Ball-bearing grease: medium consistency; operating range up to 100 deg. F. Pump grease: very stiff, water resisting, for packed gland bearings. Axle grease: medium consistency, high adhesive qualities. E.P. grease: medium soft leaded grease for roll-neck bearings, etc. "Keenolised" greases: incorporating zinc oxide for anti-corrosion and anti-wear, for heavily loaded plain and anti-friction bearings.

Germ Lubricants Ltd.
Cup greases: N.L.G.I., Nos. 1-4 consistencies, for bearings. Gun greases: soft for power feed, medium soft for hand gun. Ball-bearing, axle and extreme pressure greases.

Shell Group of Companies
General purpose greases of varying consistencies. Heavy-duty greases containing high viscosity oils for heavy-duty plain bearings. Ball and roller bearing greases suitable also for centralised lubrication systems. Extreme pressure greases for heavy-duty ball and roller bearings.

Trier Bros. Ltd.
General purpose greases from N.L.G.I., No. 1 consistency, for pressure dispensing equipment to N.L.G.I., No. 5, for water pumps and glands. Operating temperatures up to 120-130 deg. F.

Edgar Vaughan & Co. Ltd.
Cup and gun greases and ball and roller bearing grease: operating range, 0-140 deg. F. Light machine grease containing solid lubricants, for adding machines, etc.; operating range, 0-140 deg. F. Extreme pressure grease.

C. C. Wakefield & Co. Ltd.
Cup, gun, ball and roller bearing, axle and extreme pressure greases.

Chas. H. Windschuegl Ltd. (Agents for Beverolfabrieken N.V. Holland)
Cup greases: N.L.G.I., Nos. 1-4 consistencies. Pressure gun, pump, ball and roller bearing, and (for heavily loaded slow-speed bearings) high pressure greases.

WATER-FREE CALCIUM BASE GREASES

Chas. H. Windschuegl Ltd.
Ball-bearing grease: corrosion protective; operating range, −67 to +212 deg. F.

SODA SOAP GREASES

Alexander Duckham & Co. Ltd.
Gun grease. General purpose grease: operating range, 100-200 deg. F. Ball and roller bearing greases: heavy-duty, general purpose and high-speed grades, moderate temperatures. "Keenolised" greases incorporating zinc oxide for anti-corrision and anti-wear; operating temperature up to 25 deg. F.

Germ Lubricants Ltd.
Cup and gun greases: high melting point (300 deg. F.) Ball and roller bearing, extreme pressure and block greases (in various grades).

Shell Group of Companies
Cup and gun greases for plain bearings. Ball and roller bearing greases for high operating temperatures. Block greases. Greases incorporating wool yarn.

Trier Bros. Ltd.
General purpose greases. Ball-bearing greases of medium consistency.

C. C. Wakefield & Co. Ltd.
Cup, gun, ball and roller bearing, and block greases. High melting point greases (drop point, 400 deg. F.): medium and heavy duties.

Chas. H. Windschuegl Ltd.
Plain bearing greases, ball-bearing grease and semi-liquid grease for gearboxes.

MIXED CALCIUM/SODA BASE GREASES

Germ Lubricants Ltd.
Ball and roller bearing grease (drop point, 300 deg. F.): medium soft.

C. C. Wakefield & Co. Ltd.
Ball and roller bearing grease (drop point, 300 deg. F.): medium soft.

ALUMINIUM SOAP GREASES

Germ Lubricants Ltd.
Tenacious greases: highly resistant to water, for chassis lubrication and heavily loaded plain bearings.

Shell Group of Companies
Tenacious greases for open gears, wire ropes, etc.

Chas. H. Windschuegl Ltd.
Tenacious greases for chassis lubrication.

LITHIUM SOAP GREASES

Alexander Duckham & Co. Ltd.
General purpose greases: soft smooth for centralised lubrication systems, slightly stiffer consistency for high-speed anti-friction bearings; operating range, −50 to +300 deg. F. "Keenolised" grease: incorporating zinc oxide for anti-corrosion and anti-wear properties; operating range, −20 to +315 deg. F.

Germ Lubricants Ltd.
Ball and roller bearing greases: soft and medium consistencies for high temperature operation. Semi-fluid grease for high-speed reduction gears.

Mobil Oil Co. Ltd.
Ball and roller bearing greases: operating ranges, −65 to +40 deg. F. and −20 to +250 deg. F. Heavy duty roller bearing greases: lithium/lead base, medium consistency for duties involving shock loads.

Shell Group of Companies
Multi-purpose greases: N.L.G.I., Nos. 1-3 consistencies, incorporating powerful anti-oxidant and anti-corrosion additives. Extreme pressure greases.

Trier Bros. Ltd.
Ball-bearing greases (drop point, 350 deg F.): soft to medium consistencies.

Edgar Vaughan & Co. Ltd.
Multi-purpose grease: operating range, 0-350 deg. F.

C. C. Wakefield & Co. Ltd.
Ball and roller bearing greases in wide temperature range. Multi-purpose automotive grease.

Chas. H. Windschuegl Ltd.
Multi-purpose greases: operating range, −22 to +320 deg. F. Heavy-duty grease for heavily loaded roller and slide bearings.

GREASES WITH NON-SOAP GELLING AGENTS

Germ Lubricants Ltd.
Greases with no melting point for low and high temperature and corrosive environments; soft and medium consistencies.

Mobil Oil Co. Ltd.
High-temperature, no-melt, mineral oil-base grease for plain and anti-friction bearings; operating range, 250-500 deg. F.

K. S. Paul (Molybdenum Disulphide) Ltd.
Molybdenised no-melt compound compatible with rubber, and corrosion-resistant. Molybdenised soft bentone grease, not for anti-friction bearings.

Rocol Ltd.
Molybdenised bentone greases for general purposes; extra soft grade for high-speed (+10,000 r.p.m.) precision bearings, gyros, etc.; operating range, −40 to +400 deg. F. Rubber lubricant and solvent resisting greases.

Shell Group of Companies
General purpose no-melt grease, not for high-speed ball and roller bearings; operating temperatures up to 390 deg. F.

Edgar Vaughan & Co. Ltd.
Extreme temperature corrosion- and water-resistant grease: operating range −15 to +400 deg. F.

C. C. Wakefield & Co. Ltd.
Bentone grease for very high temperatures, up to 390 deg. F.

Chas. H. Windschuegl Ltd.
Water-resistant no-melt grease, suitable for automatic dispensing equipment; operating temperature up to 428 deg. F.

SILICONE GREASES

Midland Silicones Ltd.
Bearing greases for light to moderate loadings and high speeds and wide temperature ranges: −94 to +302 deg. F. and −40 to +392 deg. F. No-melt silicone grease; highly resistant to oxidation and corona discharge, for low-speed bearings; operating range, −22 to +440 deg. F. No-melt valve seal lubricant: stable at high and low temperature, oxidation and corrosion resistant. Stopcock and high vacuum greases; compatible with natural and synthetic rubbers; operating range, −40 to +392 deg. F.

K. S. Paul (Molybdenum Disulphide) Ltd.
Molybdenised silicone paste for high temperature lubrication, water resistant and compatible with rubber.

Rocol Ltd.
Molybdenised silicone greases and thickened fluids for extreme low or high temperatures.

Shell Group of Companies
Silicone grease for ball and roller bearings; operating temperature up to 382 deg. F. Molybdenised silicone grease for higher temperatures and heavier loadings.

GRAPHITED GREASES

Colloidal Graphite Ltd. — C. C. Wakefield & Co. Ltd.
Alexander Duckham & Co. Ltd. — Revol Ltd.
Germ Lubricants Ltd. — Shell Group of Companies
Graphite Products Ltd. Stamgo Manufacturing Co. Ltd. (assembly compounds)

MOLYBDENISED GREASES

Germ Lubricants Ltd.
Heavy duty greases: no-melt anti-seize compound; maximum operating temperature, 482 deg. F. Lithium-based wide-range grease: operating temperatures, sub-zero to 300 deg. F.

Mobil Oil Co. Ltd.
Multi-purpose lithium-based grease (drop point, 360 deg. F.).

K. S. Paul (Molybdenum Disulphide) Ltd.
High concentrate pastes for rubbing-in, etc.; temperatimes up to 500 deg. F. as paste, 750 deg. F. dry, or up to 2,000 deg. F. in inert atmosphere. Submicron molybdenised lubricants, lithium-based for ball and roller bearings. No-melt compound compatible with rubber, resistant to acids and alkalis. Bentone thickened mineral oil. Molybdenised silicone paste for high temperature lubrication in presence of natural and synthetic rubber. Special purpose molybdenised lubricants to order.

Rocol Ltd.
Molybdenised lithium base greases for general purposes and for valve seals. Wide-range bentone greases: sub-zero to 400 deg. F. for ball and roller bearings, including high-speed precision instrument bearings. Rubber lubricants. Molybdenised extreme-viscosity, extreme-pressure lubricant for high-pressure and severe rubbing conditions. Heavy-oil open gear lubricant. Molybdenised silicones for high and low temperatures too severe for petroleum lubricants; ranges, −40 to +600 deg. F. and −90 to +525 deg. F. Molybdenised diesters for instrument applications at very low temperatures. Molybdenised block greases for high temperature plain bearings.

Shell Group of Companies
Molybdenised grease for grease-gun application, and assembly and anti-seize compounds.

Edgar Vaughan & Co. Ltd.
Lime soap grease for anti-seize and high temperature applications.

GENERAL PURPOSE GREASES

British Steam Specialties Ltd. — Trier Bros. Ltd.
Alexander Duckham & Co. Ltd. — Edgar Vaughan & Co. Ltd.
Germ Lubricants Ltd. — C. C. Wakefield & Co. Ltd.
Shell Group of Companies — Chas. H. Windschuegl Ltd.

SPECIAL AUTOMOBILE GREASES

Alexander Duckham & Co. Ltd. — Edgar Vaughan & Co. Ltd.
Germ Lubricants Ltd. — C. C. Wakefield & Co. Ltd.
Regent Oil Co. Ltd. — Chas. H. Windschuegl Ltd.
Shell Group of Companies

TACKY GREASES AND COMPOUNDS FOR OPEN GEARS, TRACK ROLLERS, WIRE ROPES, CHASSIS, ETC.

Alexander Duckham & Co. Ltd. — Shell Group of Companies
Edwards Manufacturing Co. Ltd. — C. C. Wakefield & Co. Ltd.
Germ Lubricants Ltd. — Chas. H. Windschuegl Ltd.
Regent Oil Co. Ltd.

HIGH TEMPERATURE LUBRICANTS (450 DEG. F. PLUS)

Midland Silicones Ltd. — Germ Lubricants Ltd.
Mobil Oil Co. Ltd. — Shell Group of Companies
K. S. Paul (Molybdenum Disulphide) Ltd. — Rocol Ltd.
Stamgo Manufacturing Co. Ltd. (assembly compounds)

LOW TEMPERATURE LUBRICANTS (BELOW −40 DEG. F.)

Alexander Duckham & Co. Ltd. — Rocol Ltd.
Midland Silicones Ltd. — Chas. H. Windshuegl Ltd.
Mobil Oil Co. Ltd. — Shell Group of Companies

ACID AND ALKALI RESISTANT GREASES

Germ Lubricants Ltd. — K. S. Paul (Molybdenum Disulphide) Ltd.
Midland Silicones Ltd. — Edgar Vaughan & Co. Ltd.

PETROL AND SOLVENT RESISTANT GREASES

Rocol Ltd. — C. C. Wakefield Ltd.
Shell Group of Companies

NUCLEAR RADIATION RESISTANT GREASES

Shell Group of Companies

RUBBER LUBRICANTS

Midland Silicones Ltd. — Rocol Ltd.
K. S. Paul (Molybdenum Disulphide) Ltd.

ELASTIC DEFORMATION ON ROLLING SURFACES

WHEN a sphere is used as a rolling element between two surfaces it is usual to assume that the relative motion of the sphere and the rolling surfaces is not influenced in any significant way by their elastic deformation. To take the rolling bodies as rigid, implies "point-contact" between them, whereupon their relative motion is exactly determined by the simple geometry and constraints of the particular arrangement. In practice, contact does not occur at a point. The force, normal to the surfaces, transmitted by the rolling element causes local distortion, although elastic, so that contact occurs over a finite area. Owing to friction, tangential tractions may be transmitted between the rolling surfaces across this area of contact which give rise to a relative velocity between the two surfaces, which is small compared with the rigid-body motion, and usually referred to as "creep".

The creep motion results from a small amount of slip between the surfaces caused by their elastic distortion. It has been shown that slip may and, in fact, does, take place over part of the area of contact, even though the two bodies may be rolling together without sliding. A recent paper to the Institute of Mechanical Engineers demonstrated the nature of the creep motion and how the track of a ball rolling between two surfaces is affected by it.

The investigation has shown that the behaviour of the ball predominantly depends upon whether the spin velocities are small or large.

Creep depends upon the elastic properties of the materials and not to any appreciable extent upon frictional properties of the surfaces, provided that the surface asperities are small compared with the dimensions of the contact area. The axis of rotation of the ball takes up a position which makes the spin parameters equal at each point of contact. The theoretical expressions for the creep ratio based on the assumption that there is no slip at all agree roughly with the experiments.

When the spin motion is relatively large, slip extends over an appreciable proportion of the contact area, and, in consequence, the creep motion is influenced by the frictional properties of the surfaces. It has been observed that the creep velocity is influenced by surface finish, lubrication and speed of rolling, but not in any simple way which can be associated with the coefficient of friction as measured in a "sliding" experiment.

The creep (at large spin velocities) is sensitive to surface finish and may be reduced by 30-40 per cent by polishing the rolling surfaces.

The influence of a lubricant (light machine oil) is closely related to that of rolling speed. With the surfaces clean and dry the creep is unaffected by the speed of rolling within the range of low speeds used in these experiments (<20 ft./min.). Slip appears to be facilitated by the presence of a lubricant, thereby reducing the creep. But, provided that the speed is sufficiently low (about 2 ft./min.), the lubricant is squeezed out and the creep measurements differ little from those obtained with dry surfaces.

At high spin velocities the axis of rotation of the ball becomes indeterminate and therefore it is no longer correct to assume that the spin motion is shared equally by the two contact areas.

The above is based on a paper entitled "The Influence of Elastic Deformation upon the Motion of a Ball Rolling Between Two Surfaces", by K. L. Johnson, given recently at the I.Mech.E.

NEW DESIGN POSSIBILITIES WITH GLASS FIBRE-REINFORCED PLASTICS

Reinforced plastics make up [possibly the most spectacular new group of engineering materials of recent years. The applications of glass fibre—the most widely-used reinforcement—are described here

by D. PICKTHALL, B.Sc.(Tech.)*

THE very rapid development of low-pressure synthetic resins and of fibrous reinforcements has placed new structural materials at the disposal of industrial designers in the last twenty years. These reinforced plastics should not be considered as substitutes for traditional materials such as metals, for they have unique properties of their own and many manufacturers are finding that they provide great possibilities for simplification and integration of components.

The combination of flexible strands of glass, which possess a very high mechanical strength, with relatively brittle thermosetting resins has produced a range of materials which have many advantages. There are many possible variables in the reinforcement, the resins and the manner in which they are combined. The manufacturer of a product incorporating glass-fibre-reinforced plastics has direct control of the moulding, and the success of the product depends on the way he uses the materials, so great care must be taken in their selection.

* *Development department, Fibreglass Ltd.*

Raw Materials

FORMS OF REINFORCEMENT—As the glass fibres are the prime strength component of the laminate, the form they take is of great importance. The glass strands are available in a number of forms, but the basic material is a continuous filament of glass with a diameter of between 0·0002 and 0·0004 in. Fibres of this diameter would be very difficult to handle individually, so they are grouped in bundles usually of 204 filaments and held together by means of a very small amount of adhesive in the form of a size. This enables the glass strands to be handled easily for further processing.

In the form of strands the glass is still of little commercial use, and it has to be converted into products which can be handled easily in bulk and which can place the glass strands in the directions where strength is principally required.

Glass-fibre-reinforced plastics ship's lifeboat built by W. & J. Tod Ltd.

Rovings, which are groups of parallel glass strands wound into compact cylindrical packages, provide a ready supply of uni-directional reinforcement. Rods made from rovings (often used for fishing rods) can develop tensile strengths as high as 80 t.s.i. Rovings can be obtained with up to sixty strands wound together. They are used not only as uni-directional reinforcement but for winding tubes and as a source of glass for chopping.

Fabrics woven from glass yarns provide the most consistent general-purpose laminating reinforcement. The strength of the glass is now in two directions and consequently it is not possible to develop strengths as high as with rovings. By varying the quantity of glass in the warp and weft during weaving, the strength can be altered in these directions. Glass cloth, due to the extra processes necessary and the care which has to be exercised, is expensive and is only used where the maximum strength is required.

To overcome the problem of providing a general reinforcement at a lower cost than woven fabrics, mats were developed which consist of short lengths of glass strands (usually 2 in. long) which are randomly distributed as a sheet and then fixed in position by means of a "binder". The binder can be either chemical, in the form of an adhesive, or it may be mechanical in the form of "needling" —a process in which the fibres are forced between each other. These mats are the type of reinforcement most used although they do not develop high strengths due to the randomisation of the fibres. The strength is, however, essentially the same in all directions, i.e., the material is isotropic as opposed to fabrics and roving which are anisotropic.

For components where the strength is not quite so important but mouldability is the requirement, it is common practice to produce a dough incorporating chopped strands of glass whose length may be varied from ¼ to 2 in.

RESINS—There are now many thermosetting and thermoplastic resins available on the market and the range is continually expanding. By far the commonest resin in use today with glass fibres is the polyester type, but epoxy resins, although more expensive than polyesters, are worth using under certain conditions.

Both the polyester and epoxy resins can be cured to a solid at either room or elevated temperatures without pressure as there is no volatile product from their reaction. Phenolic and melamine resins however, which are condensation products of phenols and melamine with aldehydes, need pressure and temperature to cure. Both these resins give off water on curing and means must be provided for its removal. Neither material needs any additive to initiate the reaction.

Other resins which are important in specialist fields are the silicones, based on the polysiloxanes; the furanes, based on furfuryl alcohol; and p.t.f.e (polytetrafluorethylene). These have particular properties such as heat resistance (the silicones), chemical resistance (the furanes) and electrical resistance (p.t.f.e.).

The majority of resins mentioned so far are thermosetting, i.e., they do not soften on heating. It is also possible to use thermoplastic resins (which can be softened on heating) with reinforcements. However, these products are not used very widely at present, although their use is increasing in certain fields. Nylon/glass mixes are used for extrusion moulding and p.v.c. sheet, incorporating glass yarns and fabrics, is being used for general packaging materials.

The properties of the more common resins are summarised in Table 1.

PRE-IMPREGNATION—As well as obtaining reinforcements and resins separately, it is also possible for the users to obtain them combined and ready for use in moulding. With these materials the glass reinforcement, whether in the form of mats, chopped strands or cloths, is pre-loaded with a stable resin system so compounded that heat will trigger off the polymerisation reaction. These materials obviate the inconvenience of the moulder having to combine the resin and reinforcement, and enables him to concentrate on the moulding alone. Pre-loaded chopped strands always incorporate with them a high proportion of inert fillers, such as calcium carbonate, mica and silica flour. These reduce the cost of the "dough" and assist materially in the flow of the resin/glass filler through the mould and enable intricate shapes to be moulded satisfactorily.

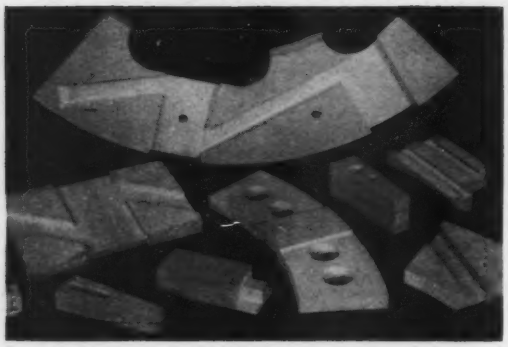
Sulphur gas seal valve using furane resin backed with polyester resin. Fibreglass chopped strand mat and woven rovings. The basic framework is of steel. Built by A. E. Griffiths (Smethwick) Ltd.

Moulding Processes

There are many ways of combining resin and fibrous reinforcement. The basic essential of all the processes is that the resin and the glass fibres must be brought into intimate contact to give a good bond between the materials. In particular, great care must be taken to ensure that as much entrapped air as possible is removed.

The simplest and still the most common method of producing mouldings is the contact process. For this, it is necessary to have only one mould and, because of this, it is possible to get only one good finished surface. Impregnation of pre-tailored glass mats and fabrics with resin is carried out with the aid of brushes and metal rollers—the "bucket-and-brush" technique. This method has the disadvantages that it is messy, high production rates are not possible, the absence of pressure makes it difficult to obtain high glass contents and the quality of the product is likely to be variable due to the human errors which enter into the process. It has the advantages that it is a simple and cheap process with hardly any limitation to size.

To overcome these disadvantages, vacuum and pressure bag mouldings were developed. Again, only one mould is necessary, usually female. To increase the glass content, and to provide a better second surface, a flexible bag is laid over the resin/glass matrix immediately after impregnation and either a vacuum is applied between the female mould and the bag, or pressure is applied to the inside face of the bag. The pressure compacts the laminate and expels



Silicone-glass cloth rotor packing blocks for use in large generators, and made by Micanite & Insulators Co. Ltd.

Aircraft battery box made in polyester/glass by National Plastics for the Varley Dry Accumulator Co.

surplus resin and, with it, much of the entrapped air from the moulding.

Although both these methods improve the inner surface of the moulding and the amount of glass present, they still do not produce laminates with the best mechanical and physical properties. By using a press and matched male and female moulds, however, it is possible to produce articles which have high glass contents, two good surfaces, accurate dimensions and much less variable mechanical properties. Unfortunately, this process requires greater capital expenditure on presses and moulds, and consequently is only justified where long production runs are envisaged.

As a further development, designed to give the quality of matched metal moulding with the low cost of the pressure and vacuum bag techniques, the resin injection system patented by Bristol Aircraft Ltd. is proving very successful. For this it is necessary to have accurate male and female moulds, but they can be made from any convenient material. In fact, reinforced plastics themselves provide the majority of these moulds. The male mould is fitted with a tailored reinforcement and the moulds are closed. Resin is pumped into the cavity between the moulds and, after it has replaced the air voids between the glass fibres, the moulding is cured.

It is important to ensure that the correct amounts of glass and resin are present in the mould cavity to obtain the maximum efficiency from matched metal and injection moulding. To assist in this, it is common practice either to pre-tailor or preform the glass reinforcements that are to be used. Preforms are probably the best method of supplying a shaped random reinforcement. A shell of glass fibres, to the shape of the mould, is produced by depositing chopped glass strands on to a perforated copy of the male tool, and holding these in position by means of a binder in the same way as in the preparation of chopped strand mats.

After completion of the moulding, it is frequently necessary to carry out finishing operations such as trimming, drilling, grinding, etc. Most machining operations can be carried out easily. It is an advantage to use abrasive wheels and diamond tipped tools as these give extremely good working lives and good finish to the component. The further bonding of other components to a moulding can be accomplished easily by using epoxy adhesives. The moulding resin and more reinforcement, particularly glass tape, can also be used. If self-colouring, by the incorporation of pigments, is not used, it is quite simple to paint the surface provided normal precautions on its preparation are taken. It is essential, of course, that any finish that is applied is compatible with the resin used in the component.

Merits of Reinforced Plastics

As will be appreciated, many factors will affect the properties of mouldings; there are within the particular types of reinforcements and resins a considerable number of minor variables. For example, polyester resins may be made more heat resistant, fire resistant, flexible, etc. On the glass side, there has been a great deal of work done to improve the adhesion of resin to glass by the addition of keying agents to the surface of the glass. Consequently, there is an infinite number of possible combinations of glass, resin and moulding methods. This has to a large extent retarded the acceptance of reinforced plastics by the designer as a structural material.

One of the most controversial aspects of the material is its strength. It has often been publicised as being stronger than steel, but such broad sweeping comparisons are merely approximations and are often wrong. The major characteristic of glass-fibre-reinforced plastics is the very close proximity of the yield point to the ultimate strength, whereas most other structural materials have yield strengths much below their ultimates. Hence, reinforced plastics can be designed to the ultimate, but this removes one factor of safety in that metals can yield without rupturing whereas reinforced plastics cannot. For a great deal of design work the ultimate strengths are relatively unimportant and the "stiffness" of the material is of prime importance. In this respect, reinforced plastics cannot develop moduli as high as steel and aluminium. This, of course, can be an advantage but usually it is not.

It can be seen from Table 2 that there is a general reduction in strength and moduli as the fibre orientation becomes more random. Another important feature is that the materials do not have the same strengths in tension and compression; this is due to the glass being the major load bearer in tension, whereas in compression it is the resin which is the load bearer. It is when the specific strength is considered that the reinforced plastics components show themselves superior to normal materials.

A further disadvantage of the material is the tendency for the laminate properties to vary due to manufacturing variations such as moulding method, glass content, type of resin and its method of cure. Because of these factors it is still necessary to provide sufficient margins of safety in the design of components.

Electrically, both the glass and the resin used are excellent insulators. The relative advantages of the different materials are naturally very important, and the final decision of which type to use is often based on its heat stability.

Corrosion resistance is one of the principle claims made for the adoption of reinforced plastics and although the materials do not suffer from corrosion, i.e., oxidation, as

TABLE 1. Typical properties of resins used in reinforced plastics

	Polyester	Epoxy	Phenolic	Melamine	Silicone	P.T.F.E.
Specific gravity	1·1–1·46	1·1–1·3	1·25–1·31	1·48	1·82	2·1–2·3
Tensile strength, 1,000 p.s.i.	4–10	4–13	6–9	7–13	4–4·3	1·5–3·0
Tensile modulus, 10^5 p.s.i.	1·5–6·5	4·5–5·4	4–10	8–10	—	0·38–0·65
Volume resistivity, ohm/cm.	10^{13}–10^{16}	10^{12}–10^{17}	10^{11}–10^{16}	10^{11}–10^{14}	10^{16}	10^{15}–10^{19}
Dielectric strength, volts/mil.	340–570	400–500	300–400	300–400	350–400	400–500
Water absorption, %	0·15–0·60	0·05–0·13	0·1–0·4	0·3–0·5	0·2–0·4	0·005
Max. service temp., °C	120–150	120–320	80–120	100	230	260
Effect of:						
weak acids	None	None	None–slight	None	None–slight	None
strong acids	Variable	Variable	Variable	Attacked	Slight	None
weak alkalis	None–slight	None	None–slight	None	None–slight	None
strong alkalis	Attacked	Slight	Decomposes	Attacked	Variable	None
organic solvents	Generally good	Generally good	None	None	Generally good	None

TABLE 2. Effect of Type of reinforcement on mechanical properties (laminating resin polyester)

	Unidirectional	Satin Weave Cloth	Plain Weave Cloth	Woven Roving Cloth	Chopped Strand Mat	Moulding Compounds
Specific gravity	1·8	1·8	1·7	1·8	1·55	1·55
Tensile strength, 1,000 p.s.i.	105·0	44·0	39·0	38·0	25·0	12·0
Tensile modulus, 10^6 p.s.i.	6·0	2·3	2·0	2·8	1·3	—
Flexural strength, 1,000 p.s.i.	150·0	55·0	55·0	53·0	32·0	20·0
Flexural modulus, 10^6 p.s.i.	6·0	2·7	2·5	3·3	1·5	1·3
Compressive strength	63·0	34·0	35·0	28·0	22·0	21·0
Glass by weight, %	65·0	62·0	55·0	60·0	40·0	40·0
Relative impact strength	8·5	3·5	3·0	7·0	2·5	1·0

TABLE 3. Effect of type of resin on mechanical properties of laminates—glass cloth reinforcement

	Polyester	Epoxy	Phenolic	Melamine	Silicone	P.T.F.E.	Phenolic Paper
NEMA Grade	—	G–10	G–3	G–5	G–7	—	XXXP
Specific gravity	1·76	1·8	1·65	1·9	1·68	2·2	1·3
Water absorption, %	0·6	0·08	1·5	1·1	0·08	0·03	0·38
Tensile strength, 1,000 p.s.i.	29·0	44·0	25·0	37·0	27·0	10·0	16·0
Flexural strength, 1,000 p.s.i.	53·0	75·0	25·0	48·0	30·0	14·0	21·0
Compressive strength 1,000 p.s.i.	58·0	50·0	50·0	70·0	45·0	20·0	28·0
Approx. relative cost	1·0	1·14	0·96	0·85	2·1	5·7	0·41

do most ferrous materials and aluminium, they are considerably affected by some environments, particularly moist conditions. The nature of the attack of water on glass reinforced plastics is still not completely understood, but the ingress of moisture into a laminate appears to attack the resin/glass interface and destroy the bond. Translucent corrugated sheeting is a typical example of this: if the glass fibres are close to the surface, the interface is eventually attacked and the pattern of the fibre, which was at first hardly discernible, begins to stand out and the sheeting becomes semi opaque.

Whereas water alone may not have much effect on a material, the combination of moisture with heat is probably one of the worst environments to which polyester-glass laminates can be exposed. This has led glass fibre manufacturers to provide protection for the glass surface in the form of keying agents which are also fully compatible with resins and so improve the adhesion. Even now this problem is not completely solved and further work is necessary in this field. The type of glass to be used under such hot moist conditions must be very carefully considered. Although both alkali and "E" type glass are available, it is advisable that "E" glass, which contains a very low alkali content (not greater than 1 per cent), should be used. Once moisture has reached the resin/glass interface it begins to leach out the Na_2O and K_2O components of alkali type glass, so forming alkali solutions which may be quite strong due to the absence of any liquid flow within the laminate, and this further attacks the structure of the laminate.

The tables of properties so far given represent the strengths of laminates which have been brought to their ultimate strength relatively quickly. While these provide a basis for design, the behaviour of the material under continuous or cyclic loading must be considered. It should be also noted that the strength losses can also vary with different resins within any one family. This again emphasises the difficulty of forecasting the life of any specific component without getting experimental data on the perform-

Polyester/glass aircraft fuel drop tanks, 75 ft. long, produced by Bristol Aircraft Ltd.

TABLE 4. Relative fatigue strength of various materials

Material	Specific Tensile Strength	Specific Fatigue Strength at 10^7 cycles (notched specimens)	% Retention
	p.s.i./lb./cu. in.		
Polyester/glass cloth	660,000	150,000	22·7
Epoxy/glass cloth	770,000	240,000	31·1
Aluminium alloy	760,000	95,000	12·5
Steel	300,000	180,000	60·0
Titanium	920,000	70,000	7·6

TABLE 5. Comparison of reinforced polyester with structural steel and Duralumin

	Duralumin	Chopped Strand Mat	Satin Weave Cloth
Resist. to elong.	2·8 (1·02)	18·4 (3·15)	9·6 (2·2)
Strength in tension	1·1 (0·38)	3·1 (0·62)	1·6 (0·37)
Resist. to bending	1·0 (0·37)	2·7 (0·54)	2·1 (0·48)
Strength in bending	1·4 (0·5)	1·6 (0·32)	1·2 (0·28)

For comparison, structural steel is taken as unity.
Figures in brackets indicate relative weight, other figures relative thickness, to give similar properties.

ance of a particular combination. If a large factor of safety is given, this preliminary experimental work is not necessary, but full advantage is not being taken of the material.

For many applications fatigue strength is the limiting factor. In this respect, although reinforced plastics are considerably affected by cyclic loading, the effects are in general less than with most other materials. Fatigue strength

These etching troughs, installed by Sun Printers Ltd., were moulded by Wemyss Woodhouse Ltd. using Cellobond polyester resin and glass fibre.

at 10^7 cycles is for polyester laminates 20-25 per cent of their short-time ultimate strengths, and 30-33 per cent for epoxy laminates. Table 4 shows how this strength drop relates to conventional materials. It can be seen that resin/glass laminates show a strength retention in fatigue considerably higher than for aluminium alloys, and in certain cases better than some steels. One vital advantage of plastics components over non-ferrous metals is that they are much less notch-sensitive and surface finishing is not as important. Also the high damping characteristics of the materials tend to prevent resonance and drumming. The materials do also show continuous creep under low permanent loadings. However, the deformation is small and the creep rate can be so low that it is insignificant over long periods.

Applications

An attempt has been made in the previous sections to discuss the general properties of glass-reinforced plastics. The products made from it may vary in size from a slip ring made of dough moulding compound measuring $\frac{1}{2}$ in. diameter up to a boat 50 ft. long. Thus there are applications in all branches of industry where the material can be used to advantage. The ease of fabrication together with its light weight makes it an ideal material for use as ducting in the confined spaces of aircraft fuselages. Its resistance to impact, the elimination of rusting and the reduction of drumming make it ideal for many road transport applications. The far sleeker lines of the new railway diesel locomotives are made easier by its use. The lifeboat of wood or aluminium needs maintaining year after year without doing any work, but it needs virtually no maintenance at all when produced in reinforced plastics. In the assembly and press shops reinforced plastics jigs and press tools can speed production. In the chemical industry tanks, pipes, ducting, plant covers and pressure vessels have, when made from suitable reinforced plastics, given working lives far in excess of conventional materials. The electrical engineer can, by its use, design motors to operate at higher temperatures and hence more efficiently. Cases can be made both tough and insulating, and radomes and radar reflectors made of reinforced plastics improve the efficiency of electronic equipment.

Glass-fibre-reinforced plastics, which are being used in increasing quantities, have tremendous possibilities. The reinforcements and resins, as well as the methods of moulding, are continually being improved. The reduction in cure time of resins and the increasing uniformity of the reinforcement will enable more precise control, increase production rates and ensure reliability of performance.

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians. Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipe-work is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

SEND FOR BROCHURE No. X27

Teddington Bellows are produced in technical collaboration with the Solar Aircraft Co., U.S.A.

TEDDINGTON BELLOWS

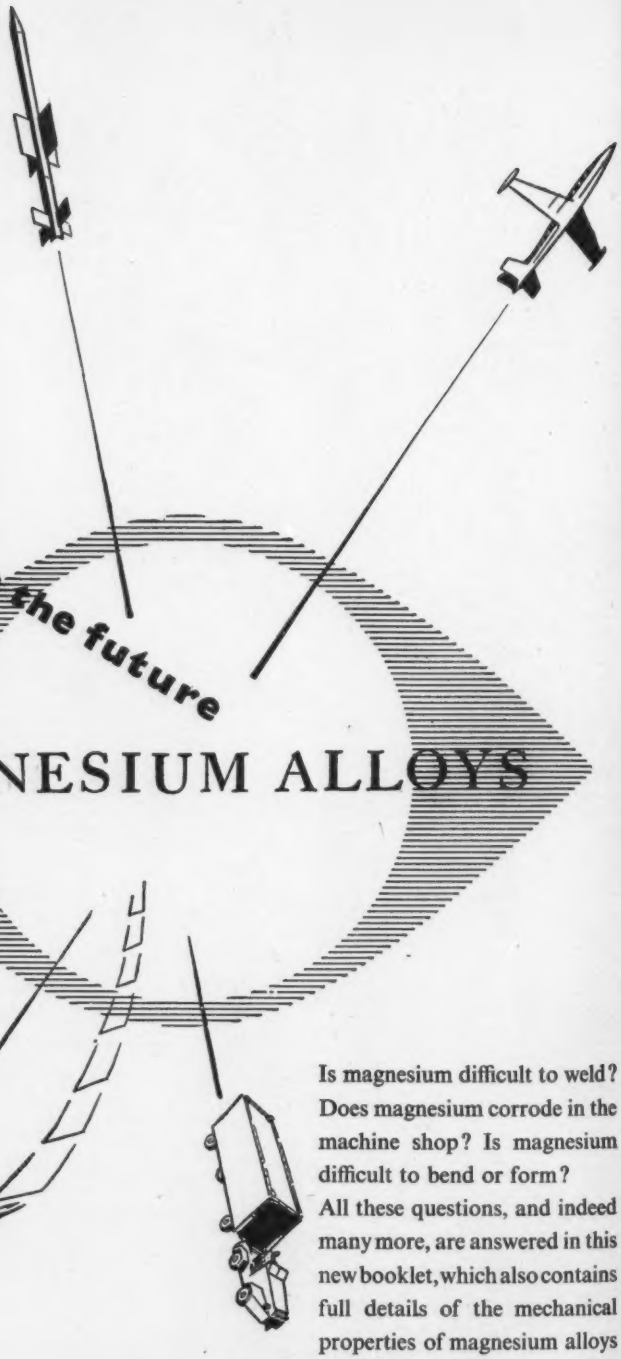
EXPANSION JOINTS

TEDDINGTON AIRCRAFT CONTROLS LTD. (*Industrial Bellows Division*)
Ammanford, Carmarthenshire. Tel.: Ammanford 2255

EMD 2143 for further information

an eye to the future

MAGNESIUM ALLOYS



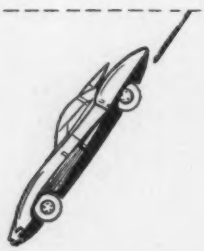
Please send me booklet

Name .....

Position .....

Business address .....

.....



BM 212

Birmetals

Visit the Magnesium Industrial Council Stand at the Engineering Materials and Design Exhibition and Conference 22-26 February 1960

Is magnesium difficult to weld? Does magnesium corrode in the machine shop? Is magnesium difficult to bend or form?

All these questions, and indeed many more, are answered in this new booklet, which also contains full details of the mechanical properties of magnesium alloys in all wrought forms.

Your reference file is incomplete without this very informative publication. Send for your copy today.

BIRMETALS LIMITED
WOODGATE WORKS
BIRMINGHAM 32

Engineering Materials and Design

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Unusual Magnets

Suitable platinum-cobalt alloys have been found to acquire remarkable magnetic properties when they undergo special heat treatment after machining operations, according to results obtained by the French company, Societe L.I.P. The length of the permanent magnets made in this material (containing about one molecule of Pt for one of Co) can be kept very short and the volume can also be reduced. Easily machined or otherwise worked, the metal is evidently suitable for magnets of all types.

The high price of the alloy—1,500 francs per gramme in France—limits it wide exploitation, but it is ideal for very small magnets like those used in clock and watch movements or measuring instruments. In the U.K. similar alloys are marketed under the name of Platinax II by Johnson Matthey & Co. Ltd.

Of special interest to instrument designers is the Cunife wire, an alloy of approximately 60 per cent copper, 20 per cent nickel and 20 per cent iron, used by National Bureau of Standards to produce permanent magnets as small in diameter as human hair. The wire has an unusual combination of magnetic and mechanical properties, including a high degree of ductility which suggested its use for very small magnets. Because of its ductility it can be cold drawn and does not have to be cast or sintered into the desired shape like most highly coercive magnet materials. Tests on larger wire sizes have shown that even if the material is cold worked to the point at which the magnetic properties are adversely affected, the initial magnetic properties may be recovered or improved by a simple heat treatment or baking.

Working Beryllium

Beryllium has a number of important properties, but its brittle behaviour has been one of the major obstacles to the widespread use of the metal and has been the cause of many expensive development programmes.

It is reported that a closed-die forging technique developed in the U.S.A. by Wyman-Gordon is capable of eliminating this brittle behaviour and results in a much more ductile material. Shapes thus produced require a minimum of machining and have ductility and isotrophy in the same order as high tensile aluminium alloy while maintaining the inherent and desirable properties of beryllium. To date, the small parts have been machined from rough shapes produced by compacting or sintering, a process which may take hours or even days. The forging method produces a part in a matter of seconds.

A new pilot plant in the U.S.A. opened by Standard Pressed Steel Co is the first in the fastener industry to fabricate beryllium into threaded parts. The company's new "exotic metals laboratory" is to be concerned in further research and development work into new fastener designs, and metals processing techniques designed to capture more of the inherent strength of the weight-saving beryllium.

Though bar stock material rated at 125,000 p.s.i. tensile strength is being produced, this does not mean that this full strength can yet be utilised in a threaded fastener for every application. Beryllium, like titanium, is exceptionally notch sensitive, and parts such as threads or bolt heads do not necessarily have the same strength as the material from which they are made.

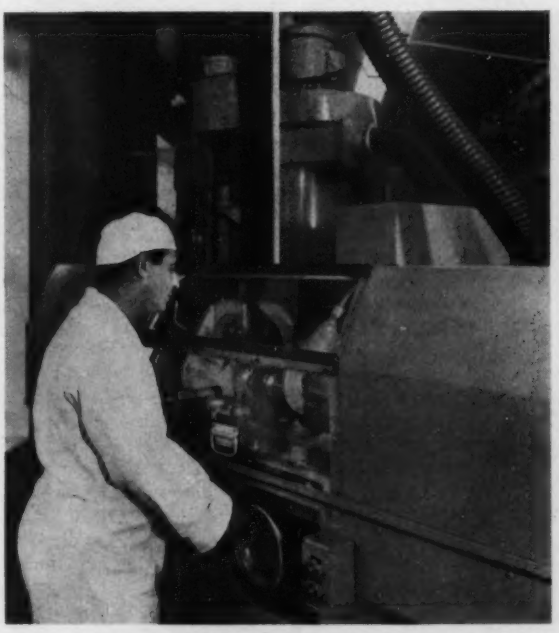
High Temperature Insulating Varnishes

Varnishes meeting the requirements of high thermal strains with increased loading capacity are known as thermal Class F types. Their adoption as insulating material in electrical machinery means higher peak load ratings without increases in component size, and plastics varnishes of this class are now used for the coating of enamelled wire. Varnishes based on terephthalic acid esters represent, with the little-used dispersion varnishes, the most important development.

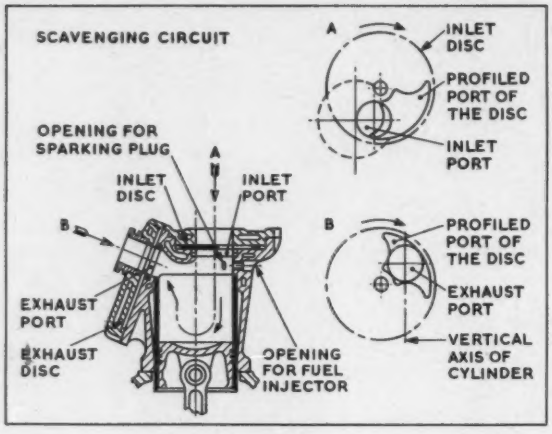
While these varnishes share the same salient properties, they may offer certain features which are specific to the brand, and which can best be evaluated from test records.

For example, the Remanex varnish produced in Germany by the Rembrandtin varnish factory possesses, according to standard test specifications, good mechanical properties, with no sticking or cracks due to thermal shock. With a softening temperature of over 300 deg. C. it is said to show high resistance and electrical breakdown voltage.

The chemical resistance against soaking varnishes with common refrigerants is good. The high resistance against permanent thermal loads is illustrated by the graphic records of tests performed according to the I.E.C. recommended procedure, and it was seen that the breakdown voltage



Completely enclosed grinder is a feature of a new laboratory of Standard Pressed Steel Co., who are producing bolts of beryllium for missile and satellite applications.



Scavenge circuit of a Soviet two-stroke engine with disc valves, described on this page.

versus time and temperature remained at the same high steady value, well beyond the limits of those of varnishes based on other raw materials.

A coil-impregnating varnish (called RL-939) produced by the same company features excellent thermal resistance. After being subjected to thermal loads of 175 deg. C. for 336 hr. and more, its elasticity is still such that bending angles of more than 180 deg. are permissible. Loss in weight after twelve weeks at 175 deg. C. is less than 35 per cent.

The higher price of these varnishes is said to be easily compensated by the improved safety, long-term dependability and bulk saving achieved.

Studying Rare Metals

A study of rare earth metals and their effect on the alloys of other metals has produced some interesting results at the Soviet Institute of Metallurgy Academy of Sciences. Scientists in the rare metal alloys laboratory there have investigated the mechanical properties of lanthanum in the temperature range of 20-800 deg. C., cerium in the range of 20-600 deg. C. and praseodymium in the range of 20-800 deg. C.

At room temperature, lanthanum, cerium and praseodymium have a hexagonal lattice structure and are not capable of appreciable plastic deformation. At higher temperature, the hexagonal lattice transforms into a body-centred cubic lattice, which is capable of considerable plastic deformation. The temperatures for maximum ductility (plasticity) were determined to be as follows: 700 deg. C. for lanthanum, 450 deg. C. for cerium and 700-750 deg. C. for praseodymium.

The laboratory has studied the effect of rare-earth metals on high-melting iron-titanium-chrome and magnesium-base alloys. Experiments with introduction of rare-earth metals into steel and iron were only recently begun, but it has been established that the addition of rare-earth metals to steel and iron greatly improves their ductility.

A popular magnesium alloy in the U.S.S.R. is the ML-5 grade (8·5 per cent Al, 0·5 per cent Zn, 0·2 per cent Mn) which, however has a low resistance to creep at somewhat elevated temperature. The creep resistance of this magnesium alloy can be substantially increased by adding the rare-earth metals of the lanthanum-neodymium series. The tensile strength of magnesium alloys also increases with the addition of lanthanum, praseodymium and neodymium. Neodymium is the most potent of rare-earth elements in improving the mechanical properties of magnesium alloys, probably due to its high solubility in magnesium. Alloying magnesium with lanthanum is impractical because the mechanical properties of such alloys are low at room temperature and the creep strength at elevated temperatures is not superior to that of plain magnesium alloys. The most practical way of adding the rare-earth metals to magnesium alloys is by means of misch metal, which contains about 50-60 per cent cerium.

Disc Valves for Two-stroke Engine

A two-stroke engine with gas distribution control by one inlet and one exhaust disc described in a recent Soviet patent is stated to yield a large power output per unit of volume, the test engine being a single cylinder with a bore of 148 mm. and a stroke of 144 mm. (2·48 litre), with a nominal compression ratio of 5·56.

The inlet distributor disc is placed horizontally in the cylinder head, and the exhaust disc alongside the cylinder at a small angle to the vertical so that the inlet port is at right angles to the piston face and the exhaust port is nearly parallel to it.

Both discs have similar profile openings and are rotated by pinions engaging with their toothed rims. The discs are sealed on the cylinder side by face seals in contact with rings, which in turn are sealed by piston rings to the cylindrical recess in which they are housed. The absence of scavenge ports reduces the overall length of the cylinder.

It is claimed that the tested engine shows a superiority over the Ricardo engine operating under similar conditions. The engine components have worked satisfactorily except for some seizures between the inlet disc and cover. Several basic advantages of the engine are listed apart from reduced cylinder length, such as elimination of reciprocating distribution gear and removal of the piston from the exhaust gas zone. The mechanism can also be used in a two-stroke diesel engine.

Hydraulically-supported Thrust Bearings

Sufficient data has been accumulated to assert the advantages of a new type of Soviet-developed thrust bearing, where the lower segment plates of the main thrust bearing for a large hydrogenerator are hydraulically supported. Such hydraulically-supported thrust bearings are said to be highly reliable for a specific loading of 60-80 kg./cm.^{2} at the bearing surface. Six hydraulically-supported thrust bearings carrying a total load of 2,000 tons (specific loading of 60 kg./cm.^{2}) have been in operation for the past two years at one of the Siberian hydroelectric stations.

It is believed that a hydraulically-supported thrust bearing can be designed for very large hydrogenerators, with rotors weighing up to 6,000 tons.

Corrosion of Screws

The choice of a suitable material for screws joining light allow and steel plate assemblies is of considerable importance if a long-service life is required in corrosive environments, including even normal atmospheres. The Light Metals Test Institute in Milan has exposed to corrosion in an industrial atmosphere a series of aluminium plates coupled to hot galvanised steel plates by means of screws of various materials.

From the tests, light alloy screws and 18/8 stainless steel screws withstood the test well. Cadmium- or chromium-plated screws gave unsatisfactory results, the cadmium plating being completely destroyed. Cadmium- or chromium-plated brass screws gave even worse results, breaking either under an applied stress or when attempts were made to unscrew them.

Eight of the aluminium plates had non-anodised surfaces and another eight were anodically oxidised.

BERYLLIUM COPPER

Normal Be Cu: containing approx. 2% Be.

Low Be Cu: containing approx. 0·4% Be with nickel or cobalt.

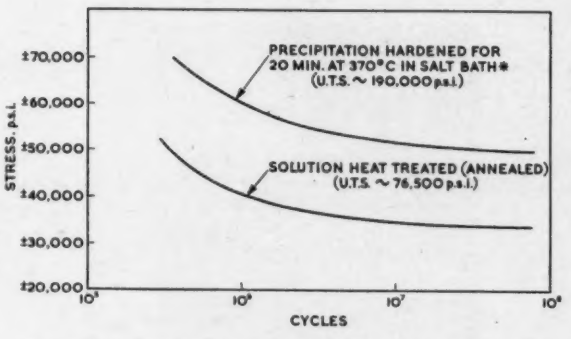
Engineering Materials and Design

DATA SHEET No. 30

Principal properties of beryllium copper

	Normal Be-Cu	*Low Be-Cu*
Density, lb./cu. in.	0·298	0·318
Coeff. thermal expansion per °C.,	17×10^{-6}	17×10^{-6}
Electrical conductivity, % I.A.C.S.		
solution heat treated	16–18	20–25
heat treated to max. hardness	20–25	45–48
heat treated to max. conductivity	32–38	48–52
Electrical resistivity at 20°C. (microhm. cm.)		
solution heat treated	9·6–10·8	6·9–8·6
heat treated to max. hardness	6·9–8·6	3·6–3·8
heat treated to max. conductivity	4·6–5·4	3·3–3·6
Temp. coeff. of electrical resistance (0–100°C.)	0·0013 per °C.	
Thermal conductivity, cal./cm.²/cm./sec./°C.		
solution heat treated	0·20	0·3
precipitation hardened	0·25	0·5
Thermal capacity (specific heat), cal./gm./°C.	0·1	0·1
Modulus of elasticity, $\times 10^6$ p.s.i.		
tension (Young's modulus)	18–19	16–17
torsion (bulk or shear modulus)	6·5–7	5·5–6·5
Temp. coeff. of elastic modulus, per °C.		
tension (− 50 to 50°C.)	− 0·00035	
torsion (− 50 to 50°C.)	− 0·00033	

Typical fatigue curves for beryllium copper[1]



* Solution heat treated and then cold worked before precipitation hardening.

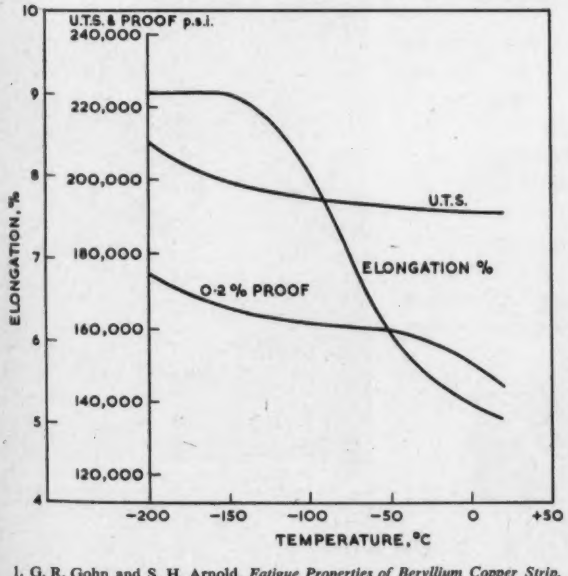
Representative mechanical properties of normal Be Cu

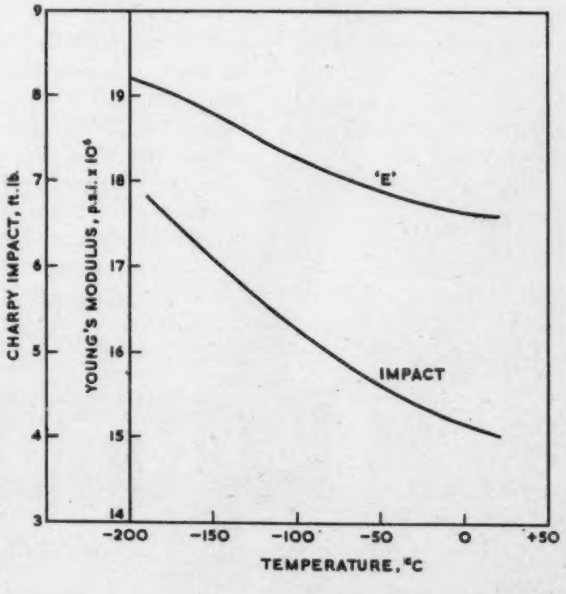
Condition	Tensile Str. t.s.i.	0·1% P.S. t.s.i.	Elong. %	D.P. Modulus
Solution heat treated:	30–35	12–16	40–60	90–130
and precip. hardened:	73–85	62–76	2–10	345–400
Cold worked, ¼ hard:	33–40	27–36	20–35	130–180
and precip. hardened:	78–89	67–81	2–6	360–420
Cold worked, ½ hard:	38–50	33–40	10–20	180–220
and precip. hardened:	89–95	71–87	2–5	380–440
Cold worked, hard:	45–55	42–50	2–10	220–240
and precip. hardened:	85–100	73–95	1–3	390–460
Castings, fully heat treated	67–77	51–69	1–3	360–430

Representative mechanical properties of low Be Cu

Condition	Tensile Str. t.s.i.	0·1% P.S. t.s.i.	Elong. %	D.P. Modulus
Solution heat treated:	17–25	9–14	20–35	65–85
and precip. hardened:	44–54	35–45	8–15	190–230
Cold worked, ¼ hard:	27–36	24–34	10–15	100–140
and precip. hardened:	49–58	44–54	8–20	210–240
Cold worked, ½ hard:	31–38	27–36	5–8	115–145
and precip. hardened:	49–58	47–54	5–12	210–240
Castings, heat treated:	34	27	10	250
Forgings, heat treated:	48	42	15	250
and cold worked:	50–55	46	10	270

Normal beryllium copper low-temperature properties (solution heat treated and precipitation hardened)[2]





1. G. R. Gohn and S. H. Arnold. *Fatigue Properties of Beryllium Copper Strip.* Proc. A.S.T.M., 1946, vol. 46, pp. 741-75.
2. Trans. A.I.M.M.E., 1954, vol. 200, pt. 5, pp. 574-80. J. T. Richards and R. M Brick.

Data courtesy Copper Development Association

EMD 2146 for further information

USE HOLDENS

'POLYPRYME'
MULTI PURPOSE PRIMER

AIR DRIES IN 10 Mins.

OVERCOAT WITHIN 1 Hr.

with air drying or stoving enamels, hammer or shrivel finishes, low bake epoxy coatings, cellulose lacquers, decorating paints.

BRUSH, SPRAY, DIP

for STEEL · ALUMINIUM
BRASS · COPPER
MAZAK · ZINTEC
HARDBOARD

ARTHUR HOLDEN & SONS LTD.
Bordesley Green Road · Birmingham 9 Tel. Victoria 2761

INSULATION AND HIGH TEMPERATURES

material answer to design problems

Sintox — an alumina ceramic of exceptional insulation characteristics — stands elevated temperatures with little change in its properties. It is widely used in the Electrical and Electronics industries, and is of great value when small components are needed. Sintox also has great mechanical strength, high thermal conductivity, resistance to corrosion and — for nuclear applications — low neutron capture cross section.

BRAZED METAL/CERAMIC TERMINAL SEALS
These seals are brazed vacuum-tight assemblies capable of withstanding elevated temperatures and pressures under conditions of continuous operation.

Sintox Technical Advisory Service

This service is freely available without obligation to those requiring technical advice on the application of Sintox Industrial Ceramics. Please write for booklet or any information required enclosing blue print if available.

SINTOX

precision engineering ceramics

SINTOX IS MANUFACTURED BY LODGE PLUGS LTD., RUGBY

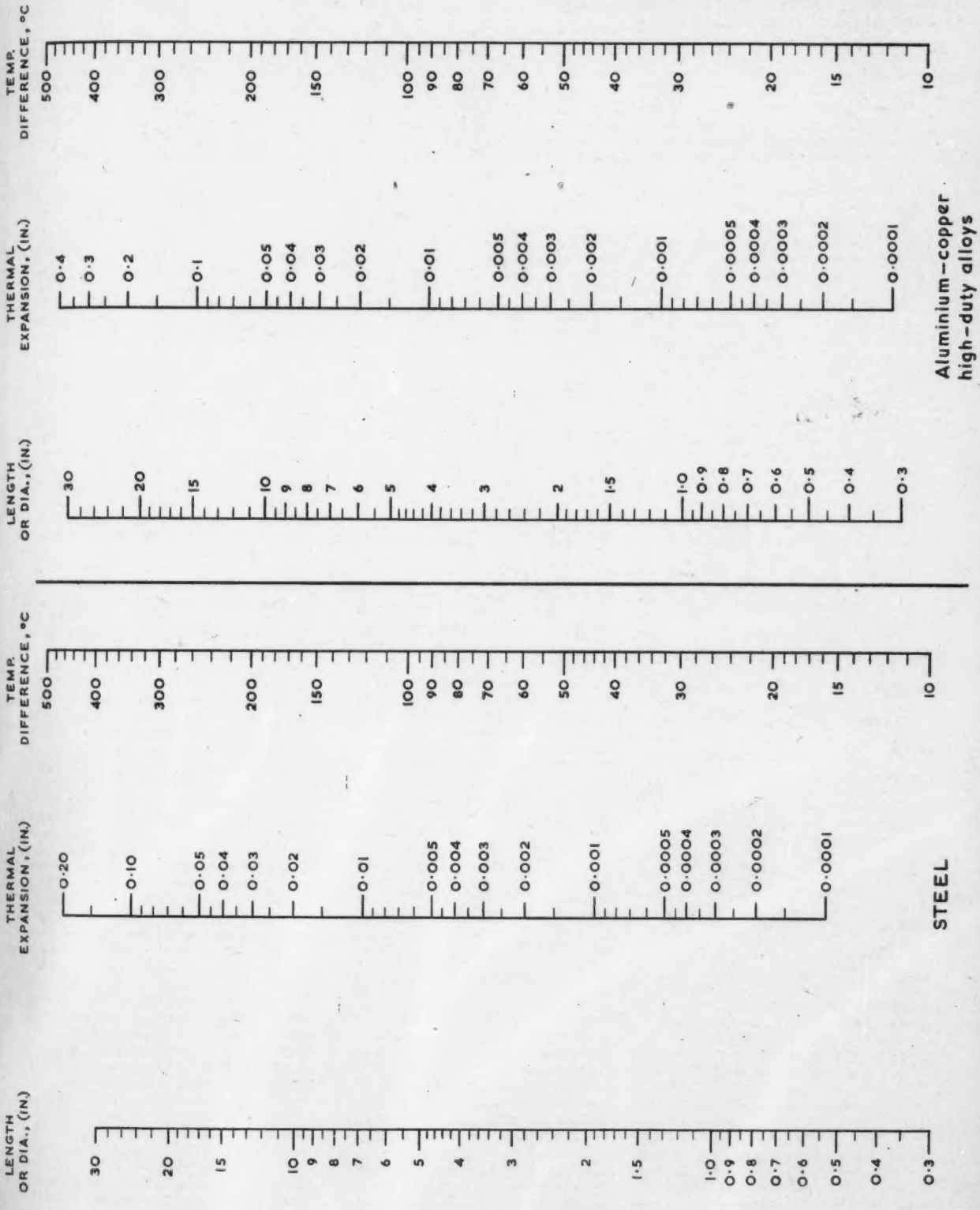
S.I.

EMD 2147 for further information

THERMAL LINEAR EXPANSION OF STEEL AND ALUMINIUM ALLOYS

Engineering Materials and Design

DATA SHEET No. 31



New Books

Product Engineering Design Manual. *Edited by D. Greenwood.* (*McGraw Hill, 70s.*)

IN setting out to cover all aspects of such a broad field as engineering design in a single volume, this has managed to achieve a high degree of success in a lucid, factual and well-arranged publication.

As specific examples of its content, there are two fully-illustrated pages on "Thirteen Ways to use Metallic Bellows", which give typical and specialist application in mechanical and electrical engineering, as well as showing how bellows movements can be transferred to other elements. Information is given in a similar fashion for fasteners on the lids of sheet metal containers, methods of attaching glass to metallic structures, how to design parts that assemble and lock by twisting, and the application of precision snap-acting switches.

Other chapters deal with mechanisms, photoelectric controls, miniature bearings, ball slides for linear motion and ball-bearing lubrication.

The book has been divided into fourteen sections each dealing with a particular facet of design, e.g., assembly; dimensions and design; drives; electrical, electronic and magnetic components; mechanical movements and linkages. It is a most comprehensive work complete with a valuable collection of tabulated data.

Energy Principles in Applied Statics. *By T. M. Charlton.* (*Blackie, 25s.*)

This useful book explains lucidly the background of strain energy problems and clarifies some of the confusion which tends to exist in this branch of applied statics. A fairly comprehensive knowledge of calculus is necessary to follow the text in detail, but the book does explain very well the conditions of equilibrium, examples of strain energy and potential energy methods, principles of virtual work and complimentary energy, these being the titles of a few of the seven chapters.

Problems in Strength of Materials. *By R. S. Paradise and G. A. Church.* (*Blackie, 25s.*)

As the title suggests, this book does not follow the now almost traditional layout, but sets down a problem and proceeds to give the necessary detailed working, bringing in the various theorems as they become applicable. While this tends to relate theory with practice which is very desirable, and rarely fulfilled, it must remain a matter of opinion whether the problems selected are representative.

There is little doubt that in this approach the student is given a sense of reality, and therefore as a text-book it is a worthy addition, but there are inevitably shortcomings when it is used as a reference.

As the authors state, it is primarily intended for degree-level students, and for this purpose it is admirable for it includes many problems for exercise. In addition to the chapters devoted to aspects usually included in this type of book, there is useful information on elasticity, strain energy, thick and thin wall cylinders and theories of failure.

Heat-resisting Steels and Alloys. *By C. G. Conway.* (*Newnes, 25s.*)

Concise data on the properties of heat-resisting steels and their alloys are invaluable to a designer, although with the rapid development in material technology such data cannot be expected to include all the latest available steels. Nevertheless, a book such as this serves a most admirable function, as the properties of the materials, which have been carefully selected by the author, illustrate the effect of composition and heat treatment, and, therefore, trends to be expected.

Emphasis is on creep data, and the various ways in which this can be recorded are exceptionally well explained in the introductory pages. For easy reference, the steels and alloys have been divided into sections: carbon and low alloy steels, bolt steels, valve steels, U.S. cast steels, austenitic and special heat-resisting steels.

The information is presented largely in the form of information and data sheets, well arranged to enable the reader to find quickly the information required.

Phenolic Resins. *By D. Gould.* (*Reinhold and Chapman & Hall, 46s.*)

In this book the practical aspects of phenolics production, uses and potential are emphasised, the pure chemistry being kept to a minimum. Moulding compounds are discussed in length, and detailed information is given on the various aspects of different types of adhesives. Laminates, bonding agents, castings and foams are adequately covered and give much practical information valuable to the designer. Each chapter is well illustrated and includes a comprehensive list of references.

Nuclear Reactor Materials. *By B. R. T. Frost and M. B. Waldron.* (*Temple Press, 12s. 6d.*)

As explained in the preface, the purpose of this series of monographs is to make known to engineers associated with nuclear power industry the properties of materials which they would be called upon to use. The scope of this book, however, can be usefully extended to engineers in general, since the information contained therein explains very simply some of the fundamental characterestics of various metals, particularly the chapter on theoretical metallurgy, which is an extremely clear exposition.

The section on structural materials deals with aluminium, magnesium, beryllium and the refractory metals, with the main emphasis on the effect of irradiation.

Other chapters cover fuel materials such as uranium, plutonium and thorium, and liquid metals for use as coolants, and there is one on metal ceramic mixtures which emphasises their utilisation as fuels, moderators and for control and shielding.

The final chapter deals with corrosion problems.

Electroplating and Corrosion Prevention. *Edited by E. Molloy* (*Newnes,* 18s.)

In most branches of industry metal finishing is an accepted part of a manufacturing routine, and the processes involved are either for decoration or protection.

This book gives a thorough coverage to all aspects of the various finishes in current use, and the opening chapters deal with the general principles of electrodeposition and preparatory work. Subsequent chapters detail the various processes and faults to be avoided, and methods of testing electroplated work. Final chapters cover chemical surface treatments and metal spraying processes. The glossary of terms will be found particularly useful.

British Glass Industry Directory and Buyers' Guide. *7th ed.* (*Iliffe, 40s.*)

The seventh edition of this guide consists of three main sections: (a) a catalogue of firms with a brief description of each of their products and services, and indicating if they are either glass and glassware manufacturers, glass manipulators and users, or suppliers of plant machinery and materials. An extremely useful addition to this is the geographical index in which companies are listed under the counties in which they are situated.

In the classified section, the companies are also arranged alphabetically under product headings. A further table of proprietary and trade names, together with a brief reference to the products, makes this guide a most comprehensive and useful addition to a library.

An Introduction to the Dynamics of Framed Structures. *By G. Rogers.* (*Chapman & Hall, 82s.*)

The treatment of the subject provided by this book is clear and factual. Chapter 1 discusses the nature of dynamic disturbances, and subsequent chapters deal with structures containing one, two and several degrees of freedom. The theory of beams, elastic and otherwise, are comprehensively covered, and there is much to interest those primarily concerned with rigid frames and floor systems.

The book is well presented, and the mathematics are of a level which should cause little trouble to either the graduate or practising design engineer.

WHAT'S NEW IN MATERIALS & COMPONENTS

Magnesium Alloy

A new magnesium alloy for use at elevated temperatures is now available as sheet, plate, extrusions and forgings. It is said to be easily machined and hot formed and to be fully weldable by the argonarc or similar processes. The properties of the alloy, known as ZTY, are said to be developed without the need for a heat treatment and the low thorium content is claimed to make it economically attractive compared with other high temperature wrought alloys of higher thorium content. Properties at room temperature are said to be 8½-12½ t.s.i. (0·1 per cent proof stress), 15-18 t.s.i. (ultimate) and 10-20 per cent elongation. The alloy may be welded to alloy ZT1, thus permitting the fabrication of structures incorporating both cast and wrought components. Magnesium Elektron Ltd., Clifton Junction, Manchester.

EMD 2199 for further information

Corrosion Inhibitors

Arugol 11 and Arugol 22 are two new inhibitors for addition to oils and greases to give improved adhesion to metal surfaces and better wetting. They are organic products, said to leave the metal surface unaffected and to impart such powerful wetting characteristics to the oil that they displace any water which may be present on the surface to be protected. Protective oils prepared from these materials are said to inhibit all types of corrosion for a considerable period. Both inhibitors are claimed to be readily soluble in oils, greases and organic solvents, to be non-toxic and to be suitable for many polishes, protective waxes and anti-corrosion sprays. Geigy Co. Ltd., Rhodes, Middleton, Manchester.

EMD 2200 for further information

Finer Glass Fibres

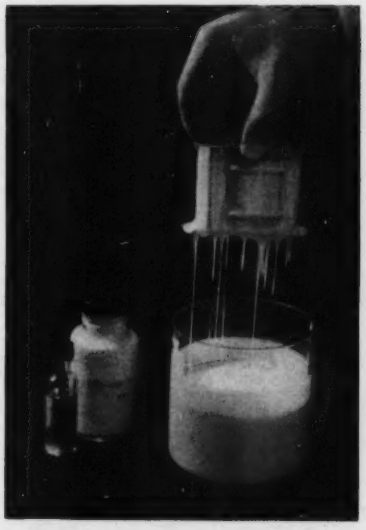
In those forms of insulation in which air spaces are enclosed by random fibres of glass it is advantageous if the individual filaments are small in diameter and do not contain solid matter in the form of dust or shot. It is also desirable that the material, when made in mattress or slab form, should possess some degree of mechanical strength. Another valuable quality is the ability of such materials to recover after being compressed, for this enables them to be compression packed and so reduce transport costs. Some degree of sound absorption is also desirable. These properties are said to be features of the new range of Crown glass fibre insulants, in which the individual filaments have been reduced from 0·00006 in. diameter (the thickness used in former ranges of standard insulants) to 0·00024 in.

The range is at present available in slab and flexible wrap form for structural, retail domestic (hot and cold applications) and for transport vehicle insulation purposes. Fibreglass Ltd., St. Helens, Lancs.

EMD 2201 for further information

Cold Cure Rubber

Cold cure Silastomer is being recommended to encapsulate and protect delicate electrical and electronic components, to impregnate electrical windings, for making flexible moulds from which resins and other materials can be cast and in a wide range of caulking, sealing and filleting techniques. It is said to be very well suited to these applications by virtue of its heat and moisture resistance coupled with excellent insulating properties.



No special equipment is required for use, and this silicone rubber needs no heat cure. It sets up at room temperature to form a heat-stable product; curing is achieved by the addition of a small amount of liquid catalyst. Midland Silicones Ltd., 68 Knightsbridge, S.W.1.

EMD 2202 for further information

Bright Gold Coating

The thin gold films which have traditionally been used for the decoration of glass and china have now found a new industrial application which utilises their excellent reflectivity of infra-red radiation.

A new method of preparing the solution of gold in an organic vehicle has enabled plastics as well as vitreous enamel, ceramics and glass to be coated with films of gold. The technique used to coat plastics, such as glass-fibre reinforced epoxy resin laminates, is to spray or brush on the organic solution of gold and bake in an infra-red oven. This treatment decomposes the gold complex to give a metallic gold film of the order of four millionths of an inch thick, which is quite resistant to abrasion and has a high reflectivity. Because of the extreme thinness of the film, it is quite economical to use and unlike most metallic surfaces it does not tarnish.

The emissivity is said to be 0·05 and 0·10 and this means that plastics coated with these very thin films of gold form excellent heat shields. Because the weight of the reflecting surface is negligible, very light but rigid plastic reflectors can be produced.

For higher temperature operation the films can be formed on porcelain-enamelled stainless steel or on purely ceramic bodies. Metallic surfaces such as aluminium, magnesium or stainless steel can also be given improved infra-red reflectivity by this technique.

Suggested applications are to reduce the rate of heat transfer on engine shrouds, drag-chute containers, tailcone assemblies and blast shields. Engelhard Industries Ltd., 145-149 Vauxhall Street, London, S.E.11.

EMD 2203 for further information

Duplex Plating

A duplex plating process that should be of value in many industries is designed to give maximum corrosion resistance together with a fully bright plate, for such applications as motor-car trim and similar accessories, A new additive is used, called Plusbrite S.F., which is a sulphur-free addition agent which, when added to the plating bath, is said to produce an electrolyte giving a semi-bright deposit of high ductility and low internal tensile stress with excellent properties.

The deposit has a columnar structure. The standard Plusbrite solution is then used to produce a fully bright finish. As the second deposit is lamellar in structure, a very high standard of corrosion resistance is said to be attainable by the duplex process. Albright & Wilson (Mfg.) Ltd., 1 Knightsbridge Green, London, S.W.1.

EMD 2204 for further information

Unbreakable Mainspring

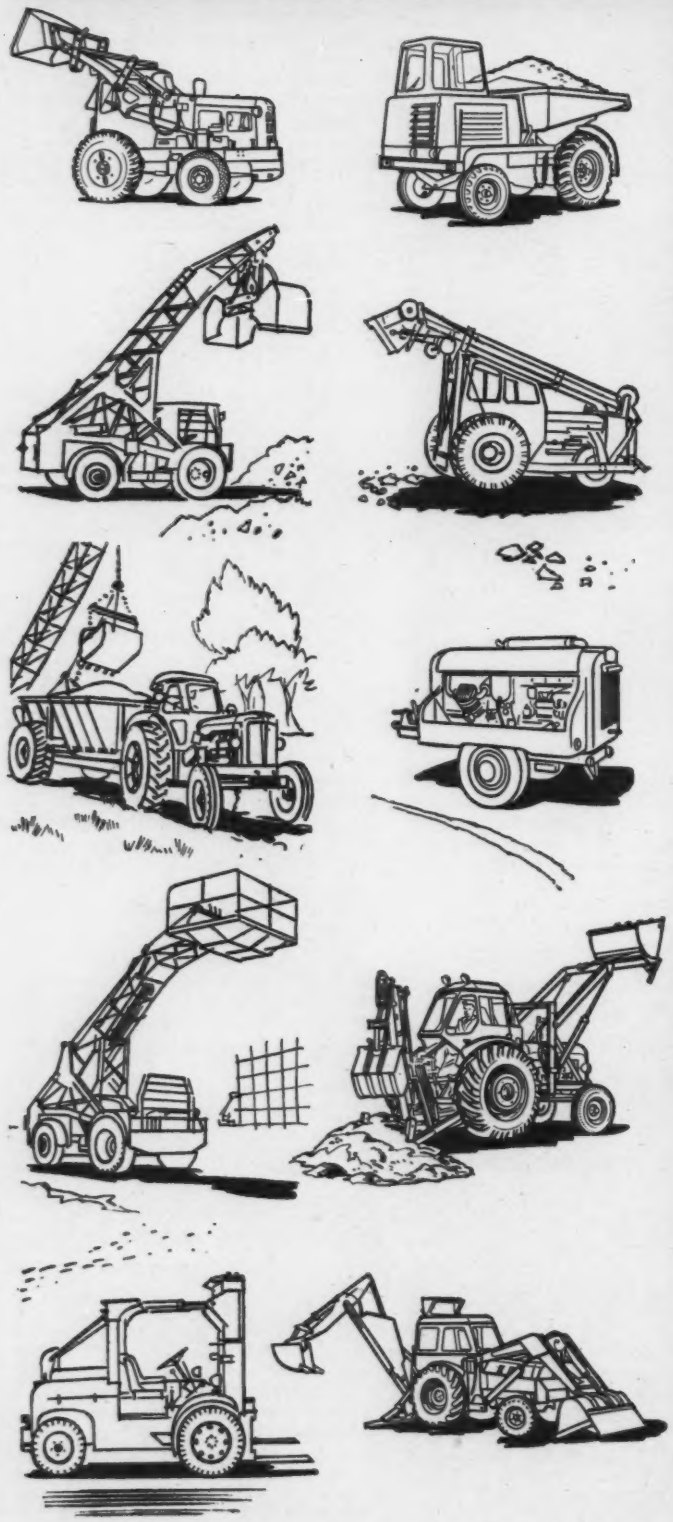
A new stainless alloy known as Fortinox has been developed specifically for the manufacture of watch and instrument springs. It is said to be unbreakable and to last the lifetime of any mechanism for which it is used. Mainsprings made from this alloy are said to show no loss of power during service. The makers claim it is the first time that such an alloy has been made in this country. Samuel Fox & Co. Ltd., 17 Westbourne Road, Sheffield 10.

EMD 2205 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

EXPERIENCED OPERATORS INSIST ON



FORDSON POWER

Men who have kept to the tightest schedules in the toughest conditions; men who have manned machines working round the clock, seven days a week; these are the men who know from experience that for proved reliability Fordson Power is unequalled. Add to reliability all the other Fordson advantages of high output, low costs, unrivalled service and spare parts organisation, and almost unlimited choice of build-ups in the 30-40 and 40-50 b.h.p. classes. That's why more Fordson power units than any other are used in industrial equipment. Write for detailed specifications.

WISE BUYERS INSIST ON FORDSON POWER

INDUSTRIAL SALES DEPARTMENT · TRACTOR DIVISION
FORD MOTOR COMPANY LIMITED · DAGENHAM ESSEX

Jointing Compound

A polyester-urethane base compound, originally developed by Rolls-Royce Ltd., is now being manufactured under the name Hylomar. In addition to normal applications, it is claimed to be specially suitable for high operating temperatures, for use with diester-base lubricants and for joint faces of extremely small sealing land width. It is said to have an operating temperature range of − 50 to + 300 deg. C. and to be resistant to a wide range of fuels, lubricants and refrigerants. The compound can be applied by brushing or spreading on to both surfaces of a joint and should be air dried for at least ten minutes before assembly. Four grades are available, varying from a stiff knifing consistency with good gap-filling properties to a light grade for good-quality joints faces where special care is necessary to avoid blocking oil-ways or other passages by excess compound. Marston Lubricants Ltd., Rock Ferry Oil Works, Birkenhead.

EMD 2206 for further information

Moisture Control Desiccants

Two new products, Sorbead R and Sorbead W, have been formulated to effect moisture control in surroundings where the presence of water vapour may cause difficulties. Moisture control, or dehumidification, is brought about by adsorption of the water vapour from its surroundings by the drying agent itself.

Sorbeads are said to have a unique bead structure, which confers certain advantages over conventional desiccants, particularly in dynamic dehumidification systems.

Sorbead R is recommended for the widest use, while Sorbread W has been developed as a specially resistant bead for use where the presence of liquid water has to be taken into account. Mobil Oil Co. Ltd., Caxton House, Westminster, S.W.1.

EMD 2207 for further information

Telescopic Joint

A telescopic joint said to provide a total axial movement of ¼ in. and an angular movement of 15 deg, is now being marketed, primarily for use with standard 4-in. pitch fibre pipe for underground and stack drainage. The new joint is a standard pitch fibre coupling, but with a narrow internally-recessed sealing ring of neoprene fitted in one end. On 8-ft. lengths of pipe the axial movement, when these couplings are used, is said to be ± 0·4 per cent. Key Engineering Co. Ltd., Larkfield, nr. Maidstone.

EMD 2208 for further information

Proximity Switch

These were designed primarily for the control of colliery hoists, but they could have useful applications wherever a moving part must operate a switch without making material contact with it.

The armature and the operating magnet are both solid permanent magnets. The armature can turn on its bearings so that its poles are close to the two yoke halves which are made of laminations of transformer steel; it is arranged to operate normally open and normally closed contacts. The switch is of the stay-put type, i.e., the throw of the switch is dependent only on the direction of the last sweep of the operating magnet. Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17.

EMD 2209 for further information

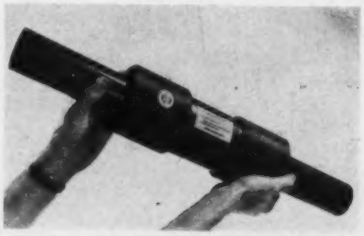
Thermal Power Element

A new thermal power element, called the Teddington Thermathrust, has recently been added to the range of thermostatic devices available. The device derives its power from a special material which has a high coefficient of volumetric expansion over a narrow temperature band. This material is contained in a non-ferrous body and, on application of heat, causes extension of an actuating rod. Although primarily intended for coolant thermostats in pressurised systems, this instrument may have other applications such as the operation of shutters and the actuation of electrical contacts as well as the warning and control of high temperatures in heavy vehicle power units. P. W. Baker & Sons (Sales) Ltd., Teddington Works, Windmill Road, Sunbury-on-Thames.

EMD 2210 for further information

P.V.C. Expansion Unit

A method of overcoming the expansion problem encountered when plastics pipe installations are subjected to temperature variations has recently been developed. The male end of the Barflo expansion unit, as it is called, passes through an O-ring; this forms the main seal and allows



telescopic action of the components contained in the cylinder. Auxiliary packing glands at each end of the cylinder enable repacking to be carried out, in order to prolong the working life of the unit.

Expansion is said to be controllable over a movement of 2-12 in., according to the size of unit used. Installed pipe runs of sizes from ¼-6 in. i.d. are possible. Special units can be constructed in sizes beyond the standard range if required. The unit is made with Geon R.A. 170 high impact p.v.c. Barflo Ltd., 56 Cavendish Place, Eastbourne.

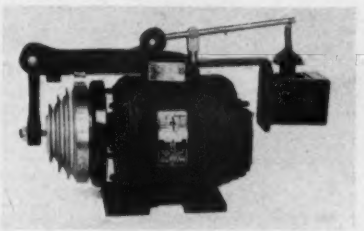
EMD 2211 for further information

Nylon Tubing

Nylon-H tubing is now being fitted to a standard range of mechanical lubricating equipment. The tubing, being flexible, can be rapidly installed in the most awkward and inaccessible positions, and will withstand pressures of up to 2,500 p.s.i. Each foot of the tubing is said to be subjected to a thorough testing at 77 deg. F., is guaranteed against bend strain and damage by impact, and will not become brittle with the prescribed temperature range of −74 to +105 deg. C. The tubing is supplied in five sizes, with outside diameters from 0·125-0·375 in. and inside diameters from 0·78-0·225 in. Wakefield-Dick Industrial Oils Ltd., 46 Grosvenor Street, London, W.1.

EMD 2212 for further information

Clutch Motor Controls



Production processes where Mardrive clutch motors are used can now be made automatic or semi-automatic by the addition of two new controls which have been developed. For automatic control, an air cylinder (where compressed air is available) is fitted to the clutch motor which can be controlled by a trip valve or similar device. Alternatively, the motor can be operated electrically by means of a solenoid. By these means, the driving unit can be fitted most conveniently for operation and the problems of mechanical linkage are eliminated. Remote control is effected simply by connecting the required length of tubing or wire. This method is shown in photograph.

The semi-automatic control was designed originally for coil-winding and other machines where a gradual acceleration of the drive machine is needed. The clutch is engaged gradually by hand or foot control, and once the speed of the driven speed is reached, it is maintained by a spring-operated latch, which is connected mechanically to a solenoid. Marine Engineering Co. (Stockport) Ltd., Bulkeley, Stockport.

EMD 2213 for further information

Pedal Control Device

This pedal control is said to have been developed for shop conditions, in order to reduce greatly the effort required to operate any machine and help eliminate operator fatigue. It enables the operator to take up the best position to suit production conditions, particularly where bulky workpieces are to be manipulated. It is designed for easy toe operation, and can include either an air valve or an electric limit switch. Udal Ltd., Interlock Works, Court Road, Birmingham 12.

EMD 2214 for further information

Small Flexible Coupling

A new miniature flexible coupling has just been marketed. It is intended primarily for electro-mechanical control circuit work (i.e., servo motor drives) where torsional rigidity between slightly misaligned parts is the main requirement. It incorporates similar features to those contained in the established Metastream-M type coupling. Initial tests indicate the coupling is likely to be satisfactory for torques up to about 12 lb.-in. Metaducts Ltd., Catherine Wheel Road, Brentford.

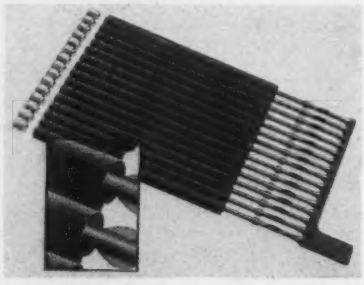
EMD 2215 for further information

Polythene Sleeves

The function of Polytel silicone grease-filled polythene sleeves is to seal the individual conductor joints against ingress of moisture into a joint in plastics-insulated communication cables. In this way, the joints are completely sealed against moisture, and thus water barriers need be fitted only to the cables in one end of each joint to prevent a "continuous pipe" effect being formed by the whole cable system. The sleeves are made from polythene tubing and are 2¼ in. long, sealed at one end and filled with a non-melting, non-hardening silicone grease which has good dielectric properties, a high degree of water repellance, oxidation resistance and a working temperature range suitable for home or overseas service. B.I.C.C. Ltd., 21 Bloomsbury Street, London, W.C.1.

EMD 2216 for further information

Traction Batteries



What is described as the most significant advance in traction battery design for half a century is embodied in the new Exide-Ironclad battery with "gauntlet" plate construction. This new design combines the traditional tubular construction of the positive plates of this brand with modern plastics techniques, resulting in a battery which is said to give up to 35 per cent more power in the same space, for about the same weight, and with a livelier performance.

Its outstanding feature is the multi-tubular gauntlet of resin-impregnated Terylene cloth which is slipped over the spines of CB.95 alloy of the positive plate and holds the active material in a firm but elastic grip. Terylene used in this application offers high resistance to sulphuric acid and oxidation, has a tensile strength of more than 40 t.s.i. and is capable of sustaining an extension of 80 per cent.

The bottom of the positive plate is a polythene moulding of special design to ensure that the Terylene tubes are sealed. Negative plates are armoured with Porvic. Cell contains are moulded from specially toughened rubber, and combined spray arrestors and separator guards are moulded in polystyrene. Chloride Batteries Ltd., Exide Works, Clifton Junction, Swinton, Manchester.

EMD 2217 for further information

Patent T-Nut

A new patented T-nut is now being marketed for use in milling machine tables, rotary tables, dividing heads, etc. It is claimed that this nut can be entered into and removed from the T-slot at any point on the table and, when in position, is automatically self-locking. Thus, it is said to effectively overcome the disadvantages of the conventional T-nut (which can be entered into the slot from a free end only), as well as saving the operator considerable time in setting up and breaking down. It is made in a range of B.S. and non-standard sizes. Kennington-Shanks Engineering Co., 61 Baker Street, Weybridge.

EMD 2218 for further information

New Publications and Technical Literature

Turner Bros. Asbestos Co. Ltd., P.O. Box 40, Rochdale: *Packings and Jointings.* 100-page volume of useful data on the company's range.

EMD 2219

Mond Nickel Co. Ltd., Thames House, Millbank, London, S.W.1: Describes in detail the properties of S.G. cast iron and lists a number of main applications.

EMD 2220

A.S.E.E., 23 Bloomsbury Square, London, W.C.1: Booklet containing details of all A.S.E.E. national events, as well as particulars of branch lectures and social occasions.

EMD 2221

Electropower Gears Ltd., Kingsbury Works, Kingsbury Road, London, N.W.9: Brochure detailing range of geared motors, speed reducers and speed increase units.

EMD 2222

Graphite Products Ltd., Northfields, Wandsworth Park, London, S.W.18: Brochure indicating the range of applications of Foliac colloidal graphite dispersions in lubricating and separating problems in industry.

EMD 2223

Fry's Diecastings Ltd., Merton Works, Prince George's Road, London, S.W.19: *Designing for Diecasting.* Useful guide to good and bad design features in diecasting.

EMD 2224

Nylonic Engineering Co. Ltd., 311b Rayners Lane, Pinner: Catalogue with technical data of nylon available in the form of rod, sheet, tube, mouldings and extruded sections.

EMD 2225

Electric Hose & Rubber Co. Ltd., Almagam Mills, Harpenden: General catalogue of general- and special-purpose and high-pressure hoses.

EMD 2226

British Aluminium Co. Ltd., Norfolk House, St. James's Square, London, S.W.1: *Aluminium Sections.* 175 pp. Illustrates a wide selection from standard range of aluminium and aluminium alloy bars and rods, and sections such as angles, channels, tees and hollows.

EMD 2227

Crofts (Engineers) Ltd., Bradford, 3: Catalogue illustrating range of available combined spur and worm double reduction gear units up to 20 h.p.

EMD 2228

Delapena & Son Ltd., Tewkesbury Road, Cheltenham: New series of folders describing range of induction heaters.

EMD 2229

Henry Wiggin & Co. Ltd., Wiggin Street, Birmingham, 16: Booklet giving basic information on Wilco-Wiggin thermometals, with thermal properties, formulæ for various shapes and temperature deflection.

EMD 2230

Hawley Products Ltd., Garman Road, Park Estate, London, N.17: Brochure showing the uses in engineering of preformed moulded fibre.

EMD 2231

Hercules Powder Co. Ltd., 1 Great Cumberland Place, London, W.1. Informative leaflet on the properties of Penton thermoplastic polymer.

EMD 2232

Crane Packing Ltd., Slough: 12-page booklet describing the Crane condenser process for enabling tubes of conventional straight tube heat exchangers to be secured and sealed off in their tube plates while still moving axially.

EMD 2233

Borg-Warner Ltd., Morse Chain division, Letchworth: Catalogue describing Morse power transmission systems.

EMD 2234

Nylon Film

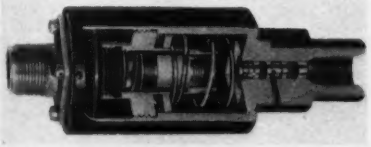
Extruded nylon film and sheet in a variety of thicknesses is claimed to possess all the chemical, physical and mechanical properties of nylon, making it useful to a wide range of applications. It is now being offered in thicknesses of 0·002-0·060 in. and in widths up to 18 in. The material is said to be grease-, abrasion- and vapour-resistant, to have a low coefficient of friction, a low permeability factor and to withstand steam sterilisation.

Since the material is available in unlimited lengths, it is ideal for mass-production stamping of thrust bearings, electric insulators, oil bearing items, backup rings, etc. United States Gasket Co., Camden 1, N.J.

EMD 2235 for further information

Pressure Switch

The type 95000 series pressure-actuated switch incorporates a snap action switch mechanism that is actuated by a piston, spring-loaded against the system pressure. High overload pressure will bottom the piston to close off completely and protect the switching element. The unit is sealed from outside atmosphere and



has been tested to 100,000 cycles. Its weight is less than 7 oz. and tubular design is said to simplify installation. It is said to operate in systems up to 4,000 p.s.i. and is recommended for aircraft and missile uses. Hydraulic Research & Mfg. Co., 2835 N. Naomi Street, Burbank, Cal.

EMD 2236 for further information

High-temperature Laminates

Two new high-temperature industrial laminated plastics are available, known as grade ARF-HT (with asbestos mat reinforcement) and grade G3-HT (with glass fabric reinforcement). They have been developed to provide new materials for the increasing interest in higher temperature laminates. Each has a modified phenolic resin binder for high-temperature resistance and is available in sheet, strip and tube form. They can be used for a recommended temperature resistance of 260 deg. C. Synthane Corp., Oaks, Pa.

EMD 2237 for further information

Vibration Monitor

The model KC-524 vibration monitor is intended to provide a means of sensing vibration levels in machinery and motors. If excessive vibration occurs, the affected unit is automatically shut down or an alarm can be sounded. The monitor is made up of two units—a scanning unit, which is used with vibration pickups, and an electronic trigger unit. Power requirement is 115 volts, 60 c/s a.c.

The scanning unit (which measures 8 × 10 × 8 in. and weighs 10 lb.) can be used with up to ten vibration pickups. Each station is monitored in sequence for a preset time interval. The scanning unit is provided with either station indicator lights or an indicator tube which remains energised after a shutdown or alarm, thus pinpointing the location of the excessive vibration.

The trigger unit amplifies the vibration signals and feeds them to a trigger circuit and a fail-safe circuit. A shutdown or alarm relay is energised when a preset vibration level is reached at any station. An electronic or pickup failure also causes a shutdown or alarm relay to activate. Kahn & Co., P.O. Box 516, Hartford 1, Conn.

EMD 2238 for further information

Airspeed Computer

A new miniature true airspeed computer, called a Minitas, consists of an extremely sensitive and accurate force balance Mach transducer, a passive resistance network and a follow-up servo. The instrument weighs 6·5 lb. and measures 5 in. diameter and 8¼ in. long. Any one of the true airspeed operating ranges and accuracies can be supplied to satisfy the requirements for high-speed aircraft, and missiles. Speeds range from 70-1,500 knots. Servomechanisms Inc., 12500 Aviation Boulevard, Hawthorne, Cal.

EMD 2239 for further information

Plastics-Rubber Hose

Rubber hose, reinforced with rigid Geon vinyl (made by B. F. Goodrich), for use in industrial applications where dusts and gases create explosion hazards has been developed.

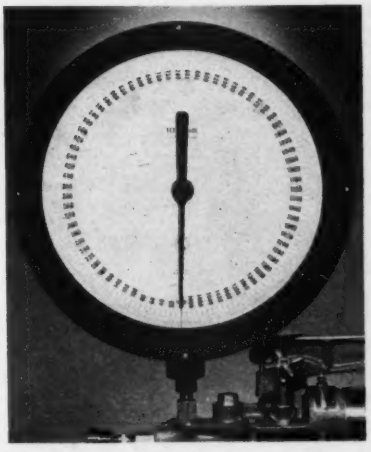
Designed to replace wire-reinforced hose, which might cause sparking and explosions when the rubber exterior

wears through and the wire is exposed, the new hose consists of a rubber core which is wrapped with a continuous coil of $\frac{3}{16}$-in. round, rigid vinyl rod for added strength and rigidity. Both the core and coil are then wrapped with an exterior layer of abrasion resistant rubber. Lawrence Hose Co., Trenton, N.J.

EMD 2240 for further information

Pressure Gauge

An advanced pressure gauge design permits a 360 deg. linear dial, with the movement calibrated to the dial with an accuracy claimed to be 0·15 per cent or better. The 12-in. dial gives the equivalent scale length of a 16-in. 270-deg. dial, but is said to provide superior readability with high accuracy in a smaller gauge. The more compact 12-in. dial also requires less panel space.



The gauges are manufactured with Bourdon tubes of Ni-Span C to maintain calibration under varying ambient or media temperature conditions, and are thus claimed to have inherent temperature compensation where it counts most, i.e., in the Bourdon tube which is the heart of the gauge. A tube tip bleed for purging and flushing the tube is fitted. Capacities available are from 15 p.s.i. to 60,000 p.s.i. Martin-Decker Corp., 3431 Cherry Avenue, Long Beach 7, Cal.

EMD 2241 for further information

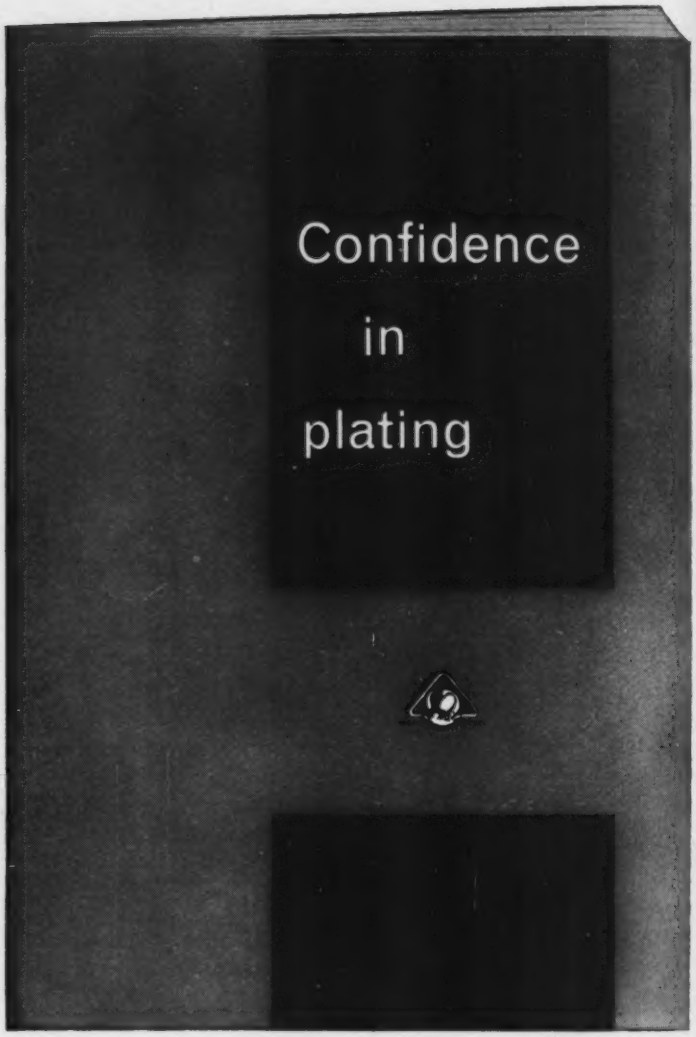
Miniature Speed Reducer

This speed reducer is said to be ideal for business machines, indicators, timers, cameras, chart drives and all low-power devices. Gears are 96 pitch, 20 deg. pressure angle spur gears of case hardened steel for long life and maximum wear. Hardened and polished input shaft, output shaft and countershafts run in special sintered nickel-silver bearing surfaces of the case itself. Gears are permanently lubricated. Principal characteristics are said to be (1) 16 oz.-in. maximum torque at low-speed shaft, (2) 3,600 r.p.m. maximum speed at high-speed shaft, (3) 0·025 h.p. and (4) 2-4 deg. backlash at low-speed shaft. It is available in thirty-four different ratios from 1 : 1 to 27 : 1. Metron Instrument Co., 432 Lincoln Street, Denver 3, Col.

EMD 2242 for further information

As a Plater you need this booklet

If you produce chromium plating you need to be aware of the Mond campaign to increase confidence in plating standards. It's described in detail in this illustrated booklet 'CONFIDENCE IN PLATING'. Here you'll see the press and TV advertising which will back this scheme in your interests. Right through the scheme runs the theme 'Chromium plating *can* be good!'



Your customers will want to know!

Do you supply the finished goods? Customers will be looking for the coloured labels of plating quality which are part of the Mond campaign.

Do you carry out plating for other people? Then show the special seal of plating standards on your estimates. For this entitles your customer to display the label.

Buyers of cars, household equipment, tools, furniture, and fittings of every type will be looking for plating they can be proud of. Make sure that *you*, as a plater, know all about this new campaign.

A new deal for Chromium Plate

FOR FURTHER INFORMATION ON THE LABELLING SCHEME COMPLETE AND RETURN THIS COUPON

Please send me your booklet 'CONFIDENCE IN PLATING' *with details of how I can join the scheme.*

NAME_____

ADDRESS_____

_____

COMPANY AND POSITION_____

_____

TGA P1

THE MOND NICKEL CO LTD

Thames House · Millbank · London · SWI

News of Industry

Durable Plastics Ltd. have recently installed new plant for applying heavy protective coatings of plastics. Claimed to be the largest plant of its kind in Europe for applying anti-corrosive finishes on larger equipment, it can handle work up to 5 tons in weight and 17 × 7 × 7 ft. in size. Coatings up to $\frac{1}{16}$ in. thick can be applied by one dipping. On simple articles, the cost is said to be comparable with rubber lining, but to be cheaper on intricate items because of the elimination of handwork.

Scientists and engineers from five leading European companies in the powder metallurgy field recently met at Swindon to discuss developments in their industry. The firms—members of the C.O.D.I.R.P. consortium—are the **Plessey Co. Ltd.** of Britain, La Metallurgie Francaise des Poudre of France, Husqvarna Vapenfabriks of Sweden, Sintermetallwork Krebsoge of Germany, and Merisinter of Italy.

Reorganisation within the **A.E.I.** group has resulted in the following changes of name as from January 1:

The B.T-H., Metropolitan-Vickers Electrical Co. and Siemens Edison Swan Ltd. change their names to Associated Electrical Industries (Rugby) Ltd., Associated Electrical Industries (Manchester) Ltd. and Associated Electrical Industries (Woolwich) Ltd., respectively.

At the same time, the newly-formed cable and construction divisions will embrace the interests of W. T. Henley's Telegraph Works Co. and Liverpool Electric Cables Ltd. Sunvic Controls Ltd. will form part of the instrumentation division. Birlec Ltd. is renamed A.E.I.-Birlec Ltd.

Fibreglass Ltd. are now supplying all their glass fibre products in the low alkali glass composition, known to the trade as "E" grade. At the same time, the prices of mats, rovings and chopped strands of this range have been reduced.

A bulk order has recently been placed by the N.C.B. for more than thirty miles of p.v.c.-coated Terylene ventilation ducting for underground mines. The ducting varies in diameter from 12-24 in. and has been stitched throughout with Terylene thread. It is said to be about three times lighter than that formerly used, has very high rot resistance, fire resistance and retention of tear strength. It has been made up by **Robert Watson & Co. Ltd.**

Shell Chemical Co. Ltd. and O. & M. Kleemann Ltd. have ended the agreement under which the Kleemann subsidiary, **Erinoid Ltd.**, has marketed polystyrene made by Shell's associate, **Styrene Products Ltd.** Erinoid will also no longer act as agents for the sale of Ziegler polythene made by Shell. Shell are now marketing identical grades of polystyrene under the name of Carinex and of Carlona high-density polythene. Erinoid continues to sell its own manufactures and grades of polythene and polystyrene.

Arrangements under which Styrene Products Ltd. manufacture polystyrene for **Kleestron Ltd.**, another Kleemann subsidiary, remain unchanged.

At a recent meeting of the **Machine Tool Trades Association** with the D.S.I.R. (one of a series to discuss changes in research and development in the machine tool industry) delegates discussed the need for closer co-operation between engineers and designers in industry, on the one hand, and the research work of universities, colleges and research institutions on the other.

Said to be the first in this country and the largest of its kind in the world, a new 3,000-ton, two column oil-hydraulic draw-down press is now being installed in the heavy forge of **Walter Somers Ltd.**

A new association between **E.M.I. Electronics Ltd.** and the Canadian General Electric Co. Ltd. has been announced. Under the arrangement, E.M.I. broadcast equipment will be distributed and serviced in Canada by C.G.E.

Some recent T.V. studio equipment, including the 4½-in. Image Orthicon camera, has been built particularly to meet North American standards.

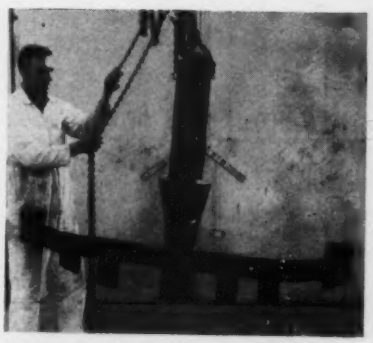
A new division for the design and manufacture of specialised machine tools has been set up by **Blackburn Aircraft Ltd.** Work on these lines has in fact been carried out for some time, but it has now become extensive enough to justify a special division.

To cater for the north of England, the **Manchester Building Centre** is expected to open in March. Work is already in hand compiling information on building materials, products and services.

The third course of studies for business executives is to be held by the **University of Sheffield** next summer. Starting in July, it will take the form of six residential sessions, each of a fortnight, during six successive university vacations. Its purpose is to enable men, who are selected by their own organisations as likely to rise to senior positions, to widen their understanding of social and business problems. Fee for the full course is 240 guineas per member.

British Oxygen Research & Development Ltd. has obtained a fluorite polychromatic—a four-channel semi-automatic vacuum ultra-violet spectrometer designed for rapid determination of carbon, phosphorus and sulphur in steel making.

A 75 per cent reduction in drafting time and a sharp decrease in human error is said to have been achieved by the use of an automatic device in programming parts for production on a giant, tape-controlled punch press. The unit, called the Auto-programmer, has been developed by the U.S. **General Electric Co.** Using half-scale dimensionless drawings, the new unit automatically produces the punch tapes used in a G.E.C. numerical positioning control system which directs operation of a 100-ton Wiedematic turret punch press.



A large plastics-coated component that has just been treated in the new plant of Durable Plastics Ltd. (See story this page.)

The **Fischer Bearings Co. Ltd.**, a Timken subsidiary in Britain, is to be purchased soon by the Fafnir Bearing Co. of the U.S.A. The business will be expanded and products will be marketed under the Fafnir name, but Timken will continue for the present to distribute Fischer bearings for replacement purposes in the U.K. through Timken Stockists Ltd.

Steel, Peech & Tozer are to spend £10 million in the next five years on the replacement of all their existing open-hearth steel melting furnaces by six electric arc furnaces of 110 tons capacity each. When completed, it will be the largest electric steelmaking plant in the world, with an annual capacity of 1,350,000 ingot tons of steel.

The **Council of Industrial Design** announce that the annual awards which have formerly been known as the "Design of the Year Awards" will in future be known as "Design Centre Awards". These go to up to twenty outstanding products exhibited at the Centre during the previous year.

The **Chesterfield Tube Co.**, a T.I. subsidiary, has reached an agreement with the Superior Tube Co. of the U.S.A. for the exchange of technical information on the manufacture of beryllium.

Designers! Is this on your shelf yet?

For the designer who knows about Glacier DRY Bearings — uses them — and points out years afterwards how right he was — it is now possible to save not only cost and maintenance in mechanical assemblies (to say nothing of oil), but designer's time and trouble, too!

Glacier Designer's Handbook No. 2 is out now!

This new handbook makes the drawing of most dry bearings quite unnecessary: all you need do is quote the Part number. In addition it provides COMPLETE TECHNICAL DATA on properties dimensions and tolerances for DU and DQ Dry Bearings and Materials — as well as on DG and DL process treatments.

THIS BOOK SHOULD BE IN THE HANDS OF EVERY DRAUGHTSMAN!

FREE OFFER:
We will send to any company, on receipt of a request from an official of the company, a copy of the Glacier DESIGNER'S HANDBOOK No. 2 for each of their draughtsmen.

We will also send a copy to any individual draughtsman who writes to us on his company's letterheading.

Write now to:

GLACIER

THE GLACIER METAL COMPANY LTD · Dept. 1 · ALPERTON · WEMBLEY · MIDDLESEX